THE RAILWAY GAZETTE
A Journal of Management, Engineering and Operation
INCORPORATING
The Railway Engineer · TRANSPORT · The Railway News
The Railway Times · Herapath's Railway Journal · THE RAILWAY RECORD.
RAILWAYS ILLUSTRATED · ESTABLISHED 1835 · THE RAILWAY OFFICIAL GAZETTE

Electric Railway Traction

SUPPLEMENT

From

January 5 to June 21

1940

LONDON:
33 TOTHILL STREET, WESTMINSTER, S.W.1

GENERAL INDEX

*[Illustrated articles are indicated thus *]*

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Electric Railway Traction

A Glance at the Future

FOR a long time past it has been increasingly obvious that industries do not appear to be capable of supporting themselves without government assistance, usually some form of subsidy, although it would seem that many more advantages might be derived from giving a subsidy to the consumer. There is at the present time a more sensible form of government assistance, and that is the granting of facilities to obtain raw materials needed for the fulfilment of contracts in hand. This was one of the salient points in the recent statement on the trade outlook for 1940 made by Mr. G. H. Nelson, Chairman and Managing Director of the English Electric Co. Ltd. With commendable perspicacity, Mr. Nelson directed attention to the necessity of facing up now to the problems which will await industry at the end of the war, and emphasised that the present heavy government spending is not prosperity in the normal state of trade and development. It is not, indeed; and a very thorough overhaul of the methods by which national business and the country's industries are carried on will be necessary if further years of chaos and frustration are to be avoided. Three of the principal points which will need recognition are that, proportionately to the monetary value of goods and services produced by industry, equivalent purchasing power must also be got into the pockets of consumers in order that the whole of the products may be disposed of (industry itself distributing purchasing power to a progressively smaller extent); that the object of industry is not work; and that export trade as now carried on is a form of economic warfare, and as such is simply the final incentive to military war.

Motor-Coach Technique

PROBABLY no feature of railway operation with which the public comes in contact has progressed so much in the last three or four years as the electric motor-coach, and although the most modern improvements are not as yet widespread, there is a constant move towards greater comfort and efficiency, *e.g.*, the 152 new electric vehicles for the Liverpool—Southport line of the L.M.S.R. Apart from the normal suburban formations, the motor-coach has been developed in directions at once more spectacular and more speedy, and fulfilling to a high degree the principles of sound railway working. Some of these are motor-coaches operating most of their time solo, such as the 800 h.p. vehicles on the Paris—Le Mans section of the French National Railways, and the Red Arrow and Jura Arrow cars in Switzerland. Others are twin-car or triple-car sets with two or three motor-coaches in the formation, and working 70 m.p.h. long-distance schedules, as in Italy; 55-60 m.p.h. schedules, as in Switzerland; or fast outer suburban services, as between Paris and Rambouillet, in France. The harbingers of these trains with a very high power-weight ratio and motor ratings at high track speeds were the Dutch streamlined sets first introduced as two-car sets in 1935. Although accelerated services played their part in the adoption of the smooth form and advanced electrical equipment of the Dutch sets, the main reason for the departure from the then prevailing form and characteristics was to save energy, for the cost of current on the Amsterdam—Rotterdam and ancillary lines was considered excessive, and further extension could not be contemplated unless the price, the specific consumption, or both, were reduced appreciably. In general, the current cost does not form nearly such a great proportion of the total operating cost as it did in Holland, and the modern forms of electric motive power have been introduced mainly in order to obtain higher speeds in conjunction with present-day standards of passenger comfort. The care paid in the selection of the electrical equipment and the contour of the body and chassis counterbalances the rise in specific current consumption which normally follows increased speed, and the accelerations to schedules may be more than justified financially and as contributions to improved operation even if the traffic does not increase. With high-speed sets working long distances on fast schedules, or operating on point-to-point schedules of 55-60 m.p.h. with a stop every 4 to 6 miles or so, correct streamlining is of great importance, but for lower speeds takes second place to weight reduction as a means of saving current and improving general operation. A certain saving in weight frequently can be obtained without much trouble or the introduction of revolutionary ideas, but if effected to a greater degree a good deal of consideration should first be given to the likely savings in current and general running costs to offset increased initial cost, and also whether the particular duties really do prove a condition where light weight is desirable.

More Electrification in Holland

ONCE again the Netherlands Railways are to extend their electrified system as a result of successful operation, and this time with a general outlook as black as it possibly could be. The lines to which standard 1,500-volt d.c. electrification is now to be applied are those from Amsterdam to Amersfoort, 44 km. (27·3 miles); Amersfoort to Utrecht, 16·5 km. (10·2 miles); and Utrecht to Hilversum, 17 km. (10·6 miles). These routes, forming an important triangle butting on the north-east part of the existing electrified area, are scheduled to be converted by the end of 1941, and will bring the electrified route mileage of the Netherlands Railways up to 367 miles. According to present intentions, the electric train mileage over the routes now to be converted will amount to 1,300,000 km. (810,000 miles) a year, and the schedules will be cut by 19 to 24 per cent. Electrified mileage in Holland has more than doubled in the last six years, principally through the prolongations from Amsterdam and Rotterdam to Utrecht, Arnhem, and Eindhoven, but as Mr. W. Hupkes, Joint General Manager, and ex-Chief Mechanical Engineer, emphasised recently, this has been practicable only because of the reduced cost of current compared with what has had to be paid for years on the Amsterdam—Rotterdam line. Coincidently with the Amersfoort extension, a number of new twin-car and five-car trains of the usual streamlined form are to be built for general circulation over the whole electrified system.

EXPRESS ELECTRIC LOCOMOTIVES FOR SOUTH AMERICA

A description of four units of advanced characteristics built for heavily-graded 5 ft. 3 in. gauge lines

By FRANK GUILLOT, General Electric Company, U.S.A.

FOUR powerful express locomotives intended for service over the Jundiahy—Rincao route, and over the Ityrapina—Bauru line when that section has been electrified, have been delivered to the Paulista Railway by the General Electric Company, of America. Both lines are laid over mountainous terrain with grades up to 1 in 54, but recent work involving the realignment of curves and the use of heavier rails has enabled top speeds to be increased, and the new design has a maximum safe speed of 90 m.p.h. compared with the 68 m.p.h. allowed for the preceding locomotives. Of the 2-Co + Co 2 wheel arrangement, the latest locomotives have a one-hour rating of 4,470 h.p. at 48·8 m.p.h. with a tractive effort of 34,500 lb.; the continuous output is 4,050 h.p. at 50·3 m.p.h. with a tractive effort of 30,000 lb. The total weight is 163 long tons, of which 120 tons are available for adhesion.

Mechanical Portion

The trucks were fabricated completely by the welding process. The main driving trucks are probably the largest single trucks ever built in the United States by this method, and provide a good illustration of the advantages in design obtainable through manufacturing flexibility where this method is used. The finished nature of much of the structural material permits the elimination of considerable machine work, and in many cases where machining is necessary it can be accomplished on the individual parts before assembly or on sub-assemblies. This eliminates the necessity of moving large heavy parts to be machined, resulting in a saving of time and labour not possible where castings are used.

Two articulated three-axle all-welded driving trucks with a four-wheel guiding truck at each end form the running gear. Each driving truck has a rigid frame extending longitudinally over the guiding truck, and forming the bumper beam and draft-gear housing. This frame extension is supported through a centre plate mounted upon a laterally-moving bolster carried on the guiding truck, and this bolster is provided with lateral restraint of a predetermined amount sufficient to properly guide the driving wheels, and to allow lateral displacement of the guiding wheels relative to the driving wheels when negotiating curves.

Each guiding truck has a tail piece attached to its inner frame which in turn is linked to a spring-restrained rocker mounted on the main driving truck frame. This device is designed to prevent undue oscillations of the guiding truck around its centre plate and adds stability at high speeds. Driving and guiding trucks are equipped with an equaliser system consisting of leaf springs with coil springs at the end support and equaliser beams connecting the inner ends. By this construction the total weight of the locomotive is evenly distributed over all axles. With the exception of wheels, axles, journal boxes, and about half the weight of each traction motor, the locomotive is spring-supported.

The braking is a combination of air and vacuum systems. Air is used for the locomotive brakes, which are applied to the driving wheels only through a single shoe to each wheel. Pressure is applied by two 14-in. × 12-in. brake cylinders for each driving truck. As the passenger rolling stock of the Paulista Railway is equipped with vacuum brakes, the vacuum system is used for applying brakes to the train, and the control of the two braking systems is coördinated on the locomotive to apply the air brakes to the locomotives whenever the vacuum brakes are applied to the train.

The main equipment room includes the entire space between the two driving cabs and is sub-divided into three compartments. The high-voltage control compartment, completely enclosed, occupies the centre, and such auxiliary apparatus as motor-generator-blower sets, compressors and exhausters are located at each end. The driving cabs at the ends are connected by passage-ways along the cab sides.

The high-voltage compartment is designed to permit the complete installation of its apparatus before it is installed in the locomotive. After assembling inside the cab, the complete unit is welded in place and final connections are made. This compartment is fitted with removable side covers, which permit access to the equipment, and end doors are also used for access to the interior. The arrangement when side covers are removed affords complete accessibility to all apparatus with ample space for men working inside, and other work can be carried on from the side aisles, thus giving access to both front and back of all apparatus at the same time. This arrangement renders inspection and repairs rapid and inexpensive. Covers of hatches in the roof over the compartment are removable.

Electrical Equipment

The six traction motors are of the commutating-pole forced-ventilated type, and are designed for 1,500 volts and insulated to operate two in series on 3,000 volts. The armature bearings are of the roller type, and each motor is suspended from the axle by two constant-level oil-filled waste-packed bearings and by a spring nose support carried on the truck transom. The drive is accomplished by means of a single wide-faced pinion on the motor shaft engaging a gear of special heat-treated steel. The gear is of two-part construction, consisting of the hub which is pressed on to the axle, and the periphery, carrying the gear face, which is bolted on to the hub. Lubrication is effected by a splash and semi-forced feed system actuated by centrifugal force.

The auxiliary equipment includes two compressors and two exhausters which are duplicates of those in existing locomotives now operating on the Paulista Railways; two 3,000/65-volt motor-generator sets, duplicates in design and capacity; and two blowers, rated at 16,000 c.f.m. at 1,350 r.p.m. each, which furnish ventilating air to the traction motors, accelerating resisters, exhausters and motor-generators.

The rotor of the blower is overhung from the motor-generator on an extended shaft from the motor end of the set. An interesting feature of this combination is the single commutator 3,000-volt series-wound motor. Included in the design are commutating poles of the so-called high-speed type which, coupled with an improved commutator construction, afford excellent commutation under varying load conditions and at all operating speeds. The use of the series motor is made possible by a direct-connected blower load eliminating the danger of over-speeding. A special construction of brush holder embodying the use of two brushes, one following the other in a given polarity

holder—one brush trailing, the other stubbing—has been employed. These brush holders are supported by moulded studs in which the metal parts are encased in an insulating material which is moulded to them at high temperatures. The generator of one of these sets supplies power for the compressors, exhausters, control and lights. It is operated at 65 volts held constant within close limits by a voltage control relay. The second generator on each locomotive is employed as an exciter for regenerative braking.

There were several advantages to be gained by equipping these locomotives with motor-generator sets of this type. The number of machines required on each locomotive has been reduced by combining the functions of several machines into one, and this results in a saving in weight and space. The use of a single commutator motor reduced the amount of control equipment and the number of connections, giving simplification of the auxiliary control. Since the sets are duplicates, the control permits either machine to be used as an auxiliary generator during motoring operations should one be disabled, or one machine can be shut down when the locomotive is doing such light work that full ventilation of the traction motors is not necessary.

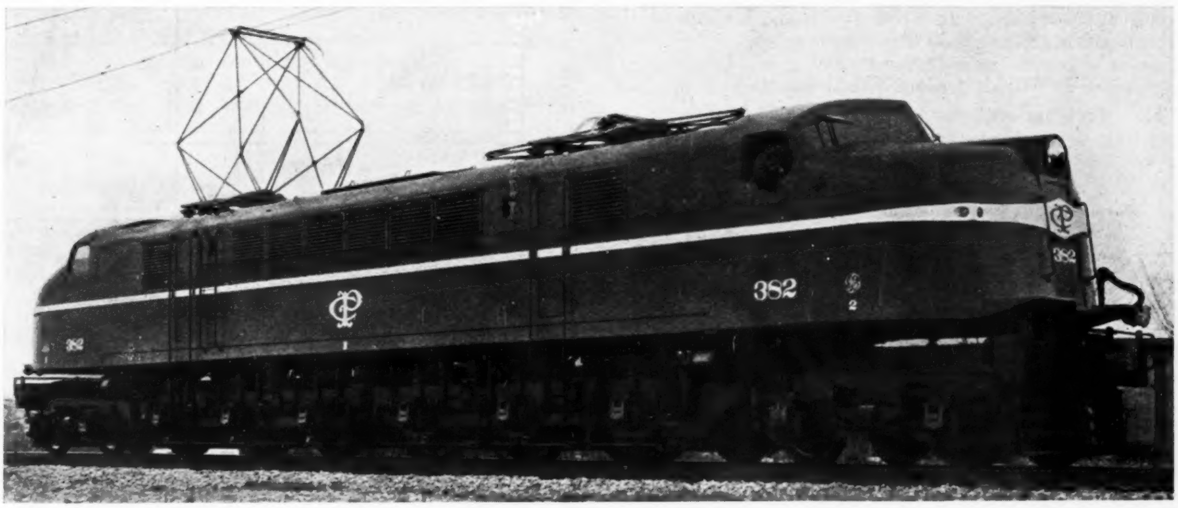
A high-speed circuit breaker is connected in the main power circuit ahead of the line and traction motor switches for short-circuit and overload protection. The rapidity of operation of this circuit breaker also affords power and substation protection by minimising the heavy demands which would otherwise be made.

Control System

The three-speed system of control employed gives traction motor combinations of six in series; three in series, each of two groups in parallel; and two in series, each with three groups in parallel. Provision is also made for multiple-unit operation should loading exceed the capacity of a single unit. The master controller is especially adaptable to the application of high-speed locomotives, and is short enough for the four handles to be conveniently located for the operator, and at the same time are below the lower edge of the front window, thus permitting maximum visibility. The main handle of this controller for the full series running connection of the traction motors moves through ten resistance steps and one full-field running position. For the connections involving three parallel groups of two motors in series eight resistance steps are used and one full-field running position. Two reduced-field running positions for each motor combination are obtained by moving the braking handle forward through two notches. The various motor combinations for regenerative braking are obtained by a third or selector handle. The 15 braking positions for motor combinations, as called for by the position of the selector handle, are secured by movement of the braking handle in the direction opposite to that for the reduced field positions. A fourth handle is used for reversing the direction of motion of the locomotive. The four operating handles of the master controller are mechanically interlocked to prevent improper operation.

The accelerating resistors which are connected into the highest current circuits of the traction motors are cast-iron grids of heavy cross-section, while those in the lower current circuits are edge-wound ribbon of chromium-aluminium iron alloy. All resistors are insulated from their frames with large mica sections while the resistor frames are insulated from their supporting structures with heavy sections of porcelain, thus providing double insulation throughout.

Overload relays in the traction motor circuit protect against overloads by automatically opening the high-speed circuit-breaker. An over-voltage relay is used to protect the equipment against excessive voltage during regenerative braking operation. Its function is to open the high-speed circuit-breaker when voltages in excess of a predetermined value are obtained. The traction motor combinations are obtained by an electro-pneumatic series-paralleling switch which is controlled in selection of the combination desired by the master controller. Regenerative braking is accomplished by using the traction motors as generators separately-excited by the generator of one of the motor-generator sets. The braking connections are obtained through a braking switch operating electro-pneumatically with some of the contactors controlled through the master controller. While regenerating, the exciter operates with a range of 45 to 58 volts depending on the motor combinations used and the speed at which the braking is being done.



New American-built locomotive for the Paulista Railway. It has an overall length of 75 ft., a total wheelbase of 66 ft. 4 in., a rigid wheelbase of 13 ft. 10 in., 46-in. wheels, and a maximum axle load of 20 tons

MODERN MOTOR-COACH CHARACTERISTICS

A study of some design and operating features relating to streamlining, weight saving, acceleration, and increased schedule speed for main-line vehicles and suburban formations

THE design of electric motor-coaches over the last 15 years or so has advanced considerably, not only in the technical details of a single vehicle but in the evolution of motor-coaches working solo on light, fast traffic, and as permanent sets of two or three vehicles operating main-line traffic, such as the Swiss and Italian streamlined formations. These advances have been accompanied by endeavours to lighten weight and to prevent the higher speeds increasing the energy consumption, and some of the problems are discussed in the following notes, which appeared from the pen of M. J. Trollux in the French journal *Electricité* a short time ago.

Working Cost Components

The operating cost per km., R, of an electric multiple-unit train or single motor-coach is made up of:

$$R = E + S + A + F \quad \ldots\ldots\ldots\ldots \quad (1)$$

in which E = the cost of the current consumed
S = train crew wages
A = maintenance and repair cost
F = general expenses, allowance for track repairs, and overheads.

The capacity of the train or trains being assumed constant, the terms A and F may be taken as being independent of the train weight and speed.

In most cases, particularly with frequent stops, the current consumption varies almost in proportion to the square of the speed and inversely with the weight. If P_o and V_o are the weight and speed of an ordinary motor-coach or multiple-unit train, and P_1 and V_1 the corresponding values for a high-speed motor-coach or electric train set, then:

$$R_1 = E_o \frac{P_o}{P_1}\left(\frac{V_1}{V_2}\right)^2 + S_o \frac{V_o}{V_1} + A + F \ldots\ldots\ldots (2)$$

The modification S_o in the crew wages takes into account the greater mileage covered in a given time by the personnel of a high-speed train.

Based on French railway statistics the above items approximate to:

E (average)	= 2·4 fr. per train-km.	=	8·3 per cent.
S (,,)	= 3·4 fr. ,, ,, ,,	=	11·7 ,,
$A + F$	= 23·2 fr. ,, ,, ,,	=	80·0 ,,
Total operating cost	= 29·0 fr. ,, ,, ,,	=	100·0 ,,

These figures show that the current cost amounts to but a small part of the total, and even an appreciable increase in price would not have a great direct influence on the operating cost per train-km.

Assuming a fixed operating cost, the following equation holds good:

$$2\cdot4\,\frac{P_o}{P_1}\left(\frac{V_1}{V_o}\right)^2 + 3\cdot4\left(\frac{V_o}{V_1}\right) = \text{Constant} \quad \ldots\ldots\ldots \quad (3)$$

In Fig. 1 is shown the equivalent variation in the relation between the weights of the two types of vehicle (ordinary and high-speed) as a function of the relative average speeds. As an example, the 65-ton motor-coaches built in 1925 for the Paris-Orleans Railway may be compared with the 37-ton motor-coaches built in 1937 for the Etat. With a

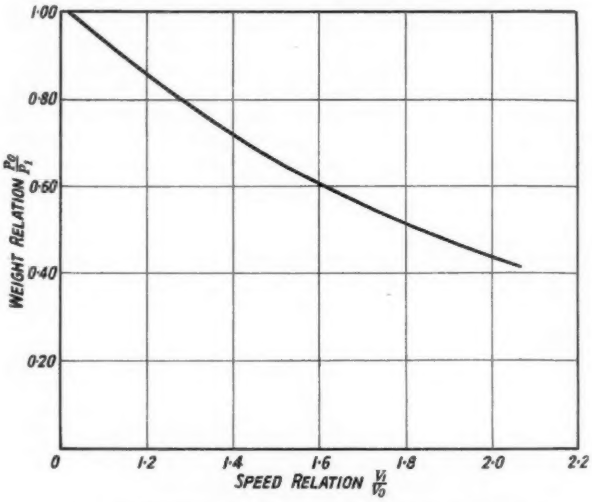


Fig. 1—Diagram showing weight ratios of motor-coaches as a function of the speed

maximum carrying capacity of 200 passengers, weighing say 13 *tonnes*, the weight relation is:

$$\frac{P_o}{P_1} = \frac{37 + 13}{65 + 13} = 0\cdot643.$$

Reading from Fig. 1 this means that for equal operating cost the lighter vehicle should be able to give a schedule speed increased by over 50 per cent., indicating that higher overall speeds do not necessarily mean greater expenses. Actually, increased schedule speed is justified if the crew wages increase at a faster rate than the cost of electric energy.

Value of Increased Speeds

Considering suburban services, increased train speeds are undoubtedly desirable, for the better the facilities provided the greater is the potential traffic, and the longer distances will passengers travel. The distance and size of residential districts round a large city depend almost entirely on the time (and expense) the suburban can spare for his daily journey, and the quicker the services the further afield will the worker tend to live. From the railway operating aspect, higher speeds increase the capacity of the line, and might be of particular value at rush hours. Further, higher speeds permit of a greater annual mileage, and it might be possible to handle the traffic with a smaller amount of rolling stock. Most of these considerations also apply to high-speed main-line electric motor-coaches or train sets, even if they are used for accelerated stopping trains over a long main line. The increased speed of such trains is a distinct advantage, for the closer together the average speeds of all trains, the greater will be the capacity of the line.

The operating efficiency of high-speed single-unit motor-coaches or electric train sets involves research into weight reduction and body contour. With light, fast vehicles the power absorbed depends principally upon the exterior

form, and the resistance of such a vehicle may be expressed in the form

$$Z = P\alpha + \beta V^2 \quad \text{......................................} \quad (4)$$

in which

Z = the resistance in kg.
P = the motor-coach or train weight, in *tonnes.*
V = the speed in km.p.h.
α = a coefficient with an approximate value of 2.
β = a coefficient depending on the body shape, and with values akin to those given in Fig. 2.

The curves in Fig. 2 show the influence of proper streamlining on vehicles of this type. At a speed of 150 km.p.h. (93 m.p.h.) the power absorbed by air resistance is seven times that necessary to overcome the rolling resistance. At lower speeds an aerodynamical form is not of importance, and weight has a greater effect than air resistance.

Any tendency for energy consumption to increase must not be confused with waste of energy. The replacement of existing stock by more modern and more expensive vehicles may be quite justified technically and financially. Consider two motor-coaches, identical except for the wheels, one having tyred wheels and the other monobloc wheels with thin rims. The wheel diameter being governed

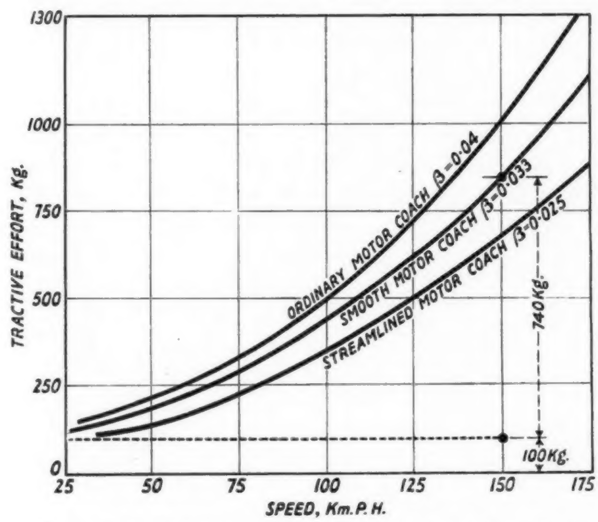


Fig. 2—Speed-tractive effort curves showing influence of streamlining motor-coaches

to some extent by the limitations of the lower part of the loading gauge, it may be assumed that the alloy steel monobloc wheels, wear on which is slight, will have a diameter when new approximating to that of the tyred wheels when a good deal of wear has occurred. With a tyred wheel diameter of 980 mm. (38·5 in.) when new, the monobloc wheels will scarcely need to be more than 900 mm. (36·4 in.) in diameter, and the saving in weight per wheel and axle assembly will be of the order of 500 kg. (1,100 lb.) if the hubs and axles are identical. The saving in weight for a double-bogie motor-coach would thus be 2,000 kg. (4,400 lb.).

Power Gain at Starting

During acceleration the actual power gain is doubled, for to the linear acceleration of the motor-coach must be added the angular acceleration of the rotating mass, and the adoption of monobloc wheels thus leads to an equivalent gain of 4,000 kg. (8,800 lb.) during acceleration periods. For a 40-*tonne* motor-coach this means a gain in power or

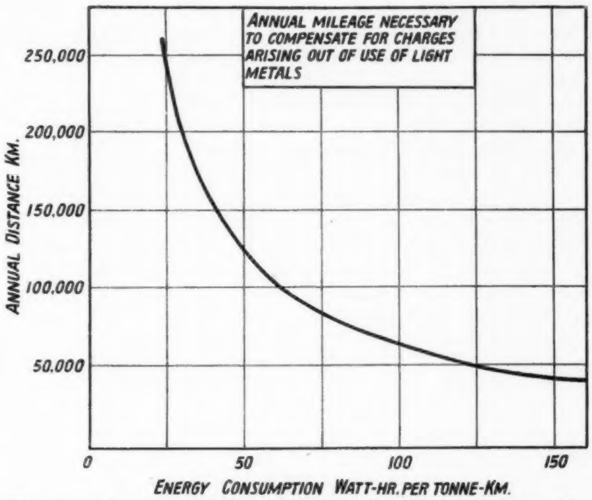


Fig. 3—Diagram showing annual mileage required to make the use of light metals in motor-coaches a paying proposition

reduction in current consumption of about 10 per cent., or, at equal power, an increase of 10 per cent. in the acceleration. This is one reason why monobloc wheels with thin rims are so much used for railcars, which have a definite limit to their power.

The higher cost of monobloc wheels must be taken into account. At each start the accelerating effort for the extra weight of tyred wheels would be :

$$\Delta = 0\cdot5\,\frac{P}{g}V^2 + 0\cdot5\,\frac{P}{g}\,r^2\,\omega^2 \quad \text{......} \quad (5)$$

in which

P = the extra weight in kg.
V = speed in km.p.h. at end of acceleration
g = acceleration due to gravity, in metres per sec. per sec.
r = radius of gyration, in this case virtually equal to the radius of the wheel
ω = angular speed of the wheel at the end of acceleration.

For a speed of 130 km.p.h. (81 m.p.h.) at the end of acceleration, and with an extra weight of 500 kg. (1,100 lb.), the accelerative force for a wheel and axle assembly would be about 66,500 kg.-m. If the motor-coach was operating

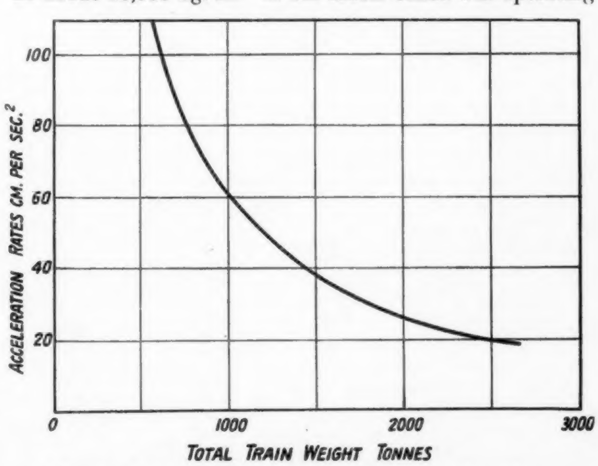
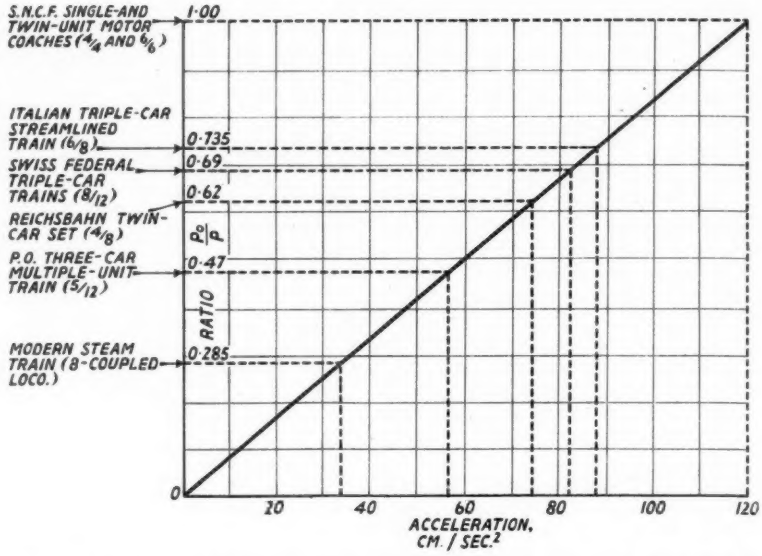


Fig. 4—Train weights and accelerations with a given substation capacity

Fig. 5—Diagram showing the accelerative capacities in relation to specific weights of various forms of electric and steam motor-coaches and trains. The figures in brackets after the train description denote, for electric stock, the number of driving axles (numerator) and total number of axles (denominator)



in short-distance service with a stop every 7 km. (4·3 miles), the force would average 9,500 kg.-m. per km. run, equivalent to an energy consumption, *C*, of about 50 watt-hr.

If *J* represents the price of two monobloc wheels and *p* is the price of current per kWh at the wheel rims (taken as cost per kWh at the outgoing busbars of the substations × 1·5 for the accelerating periods), the mileage necessary to pay for the extra cost of the light monobloc wheels by saving in current cost will be :

$$L = \frac{J}{p \times C} \quad \text{.....................} \quad (6)$$

If *J* is 7,000 fr. and the current cost 0·26 fr. per unit, then equation (6) becomes :

$$\frac{7{,}000}{1{\cdot}5 \times 0{\cdot}26 \times 50} = 360{,}000 \text{ km. } (223{,}000 \text{ miles}).$$

This distance is within the capacity of a monobloc wheel and a gain in weight of 2,000 kg. (4,400 lb.) per motor-coach, corresponding to an increased price of 28,000 fr. over a vehicle with ordinary tyred wheels, can be a paying proposition, always realising that if instead of a frequent-stop service the motor-coach was operating long-distance non-stop trains the result would be different.

The use of light metals in place of steel may give a saving in weight, for any particular detail application, amounting to as much as 55 per cent. ; that is, a *tonne* of steel could be replaced by 450 kg. of light metal. On the contra side, the increased price would average about 16,000 fr. per *tonne* of weight saved. To be a financial proposition, the use of light metals must compensate the supplementary financial charges comprising interest and depreciation, either by a saving in energy consumption, or by the better use of the rolling stock in ways such as an increase of pay load or by increased speed.

According to whether the electric energy is costly or cheap, and whether the energy consumption per unit of car weight is great or small, so will the use of light metals be justified or not. In Fig. 3 is shown, as a junction of the energy consumption in watt-hr. per *tonne*-km., the yearly mileage necessary to pay all charges, including interest and depreciation, arising from the use of light metals. The cost of current has been taken at 0·26 fr. per kWh and the combined charge for interest and depreciation at 10 per cent.

For lower energy cost or for services with low energy consumption per *tonne*-km. (e.g., freight trains), the conclusions may be quite different. This indicates that it can be erroneous to combat the problem of improvement in its economic sense by trying in every case to reduce the weight, no matter what might be the influence on the initial cost. In any case, weight saving on electric motor-coaches must not impair robustness and safety.

There is another condition which favours weight reduction in motor-coaches, and that is the current supply system from the substations, for if the motor coaches can be made lighter more of them can be started and accelerated in the same supply section without the necessity of increasing the capacity of the switchgear. In the normal French substation on a suburban system the circuit breakers limit the maximum current to about 12,000 amp., and an appreciable lightening of the motor-coaches—whether operating solo or in multiple-unit—would enable more power units to be in any one supply section at a time.

In Fig. 4 is shown the total train weight which can be moved at one time at various acceleration rates with an available power in the 1,500-volt d.c. catenary of 18,000 kW fed from one substation. Ordinary acceleration rates obtained in service are :

Steam suburban trains	30 to 40 cm. per sec. per sec. (1·0 to 1·3 ft. per sec. per sec.)
Electric suburban trains ..	40 to 60 cm. per sec. per sec. (1·3 to 2·0 ft. per sec. per sec.)
Ordinary passenger trains ..	10 to 20 cm. per sec. per sec. (0·33 to 0·65 ft. per sec. per sec.).

All these values are much less than the rates which can be obtained with the modern light-weight forms.

If the average speed is to be increased it is rarely sufficient merely to increase the starting acceleration, which is governed closely by the relation between adhesion weight and total weight ; the top speed must also be raised. Assuming a top speed of 90 km.p.h. (56 m.p.h.), the average speed between stations 7 km. (4·3 miles) apart lies between 76 and 82·5 km.p.h. (47 and 51 m.p.h.) when the acceleration rate is constant at 0·5 to 1·0 metre per sec. per sec. (1·64 to 3·28 ft. per sec. per sec.). If the speed limit is raised to 120 km.p.h. (75 m.p.h.), a schedule speed of 92 km.p.h. (57 m.p.h.) can be obtained with a constant acceleration of 0·5 metres per sec. per sec. (1·64 ft.), and 104 km.p.h. (64·5 m.p.h.) for a constant acceleration of 1·0 metre per sec. per sec. (3·28 ft.). Thus, with the same rate of acceleration the average schedule speed can be increased by 21 per cent. and 26 per cent.

ELECTRIC TRACTION ACTIVITIES IN 1939

A review of the year's work of the British railways and big four British electrical companies

ALTHOUGH electric traction work in England during 1939 involved completed electrification only on the Southern Railway—the Gillingham and Maidstone lines opened on July 2—the work on new schemes and new equipments was varied. Until the beginning of the war, work was being pushed ahead on the Manchester—Sheffield and London—Shenfield conversions on the L.N.E.R., and throughout the year the Southern Railway was proceeding with the complete rehabilitation of the Waterloo & City Railway. On the L.M.S.R. the new rolling stock for the Liverpool to Southport lines—comprising over 150 all-steel vehicles—began to go into traffic, and on the Great Western Railway consideration was given to the Merz & McLellan report on the advisability of electrifying the Taunton—Penzance main line section, a proposal which was not considered to provide a big enough return on the capital required. The London Passenger Transport Board made good progress with the £45,000,000 programme of new works and modernisation which is being undertaken by the board, the L.N.E.R. and the G.W.R. In addition to opening the new tubes from Archway (Highgate) to East Finchley, and from Baker Street to Finchley Road, the latter enabling through electric trains to run between the West End and Stanmore, a large amount of electric stock for tube and District lines was introduced, built by the Metropolitan-Cammell Carriage & Wagon Co. Ltd., the Birmingham Railway Carriage & Wagon Co. Ltd., and the Gloucester Railway Carriage & Wagon Co. Ltd., and with electrical equipment by B.T.H., Metro-Vick, G.E.C., and Crompton Parkinson.

The activities of the big four electrical companies were varied and included much work for home railways as well as for export, and in addition a good deal of valuable technical development was done in the fields of mobile and stationary traction equipment.

B.T.H.

A further order was received from London Transport for 45 sets of motor control equipment for non-driving motor coaches, together with the auxiliary wiring for these and 10 additional trailer cars. This brought the number of P.C.M. electro-pneumatic equipments ordered by London Transport since 1937 up to a total of 850. Special conversion equipment was also ordered by London Transport for an experimental diesel-electric locomotive, which is being constructed from two tube motor-coaches by cutting off the trailing ends and joining the motor ends together. A diesel-generator set is being installed for traction purposes and the locomotive will also be able to run on the track supply where this is available. For export, B.T.H. is supplying the equipment required to complete two motor-coaches being built by the Metropolitan-Cammell Carriage & Wagon Co. Ltd. for the Bombay, Baroda & Central India Railway, to supplement the original 40 equipments supplied by B.T.H. in 1927.

Five pumpless rectifier equipments, complete with the associated a.c. and d.c. switchgear are being built to augment the supply to the electric railway system in the London district. Each equipment is rated 1,500 kW, 630 volts, and consists of four pumpless rectifiers in parallel, operating six-phase. These rectifier equipments are to be installed in two existing substations, where they will replace motor-converters. Another order covered four pumpless rectifier equipments, each rated 2,000 kW, 630 volts, together with all the associated a.c. and d.c. switchgear, for installation in a new substation on the London underground system. Each equipment is to consist of four pumpless rectifiers in parallel, and will operate 12-phase. This installation will form the largest pumpless rectifier substation in existence.

An important contract in hand comprises a dozen 1,500-kW 630-volt 12-phase rectifiers, with all auxiliaries and associated a.c. and d.c. switchgear. These are to be installed in five substations on the extension of the Central London Line of the L.P.T.B., and are to be controlled from a common control room by supervisory gear employing merely a single pair of wires for the controls and indications.

For the New South Wales Government Railways two B.T.H. 1,500-kW 1,530-volt rectifier equipments have been supplied and are now being installed in a new substation at Caringbah. These rectifiers are equipped with an up-to-date type of grid control for over-compounding and arc suppression.

In South Africa, two additional 1,500-kW rectifiers and one 2,500-kW rectifier, all for 3,000 volts d.c., have been completed, and are now being installed to augment the

All-steel suburban motor-coach built at Derby works, and with English Electric electrical equipment, for the Liverpool-Southport lines, L.M.S.R.

Metro-Vick traction motor and control equipment built at the Trafford Park works for the electric locomotives of the Manchester-Sheffield conversion scheme of the L.N.E.R.

supply on the Johannesburg suburban system, which was converted a year or two ago, and fed mainly through B.T.H. rectifiers. Like the original rectifiers, these are arranged for arc suppression by grid control in the event of backfire or short-circuit, with automatic resetting and with discrimination between backfire and short-circuit. In consequence of the satisfactory operation of the grid-controlled rectifiers for a.c.-d.c./d.c.-a.c. working installed on the Natal electrified railways, the South African Electricity Supply Commission placed an order shortly before the outbreak of war for four more rectifiers, substantially duplicates of the original equipments, for extensions near Durban. These prolongations of the electrified system are both along the coast and inland.

Metro-Vick

The two latest orders for metadyne equipments for the London Passenger Transport Board, which totalled 73 sets, were completed, and the total number of such equipments in service on the L.P.T.B. is now 125. An important order was received from the L.N.E.R. for eight high-speed passenger locomotive electrical equipments for use on the Manchester to Sheffield electrification scheme. These locomotives, which are being built at the Doncaster works of the L.N.E.R., will weigh about 102 tons, and will operate on 1,500 volts d.c. They will be equipped with six motors each of 345 h.p. on the one-hour rating, which will drive three axles through the Winterthur form of individual axle drive. The locomotives are designed for a maximum speed of 90 m.p.h. and must be capable of hauling a 350-ton passenger train on the level at 75 m.p.h. Metro-Vick is also completing an order for 70 equipments for double-bogie locomotives for the Manchester—Sheffield scheme.

Further work for the Polish State Railways was in hand until the beginning of the war. It included four double-bogie electric locomotives exactly the same as the six previously supplied. As before, the electrical equipments were being supplied from this country, the mechanical portions being constructed and the locomotives erected in Poland.

English Electric

Most noteworthy of the traction activities during 1939 was the delivery of the complete electrical equipments for the 152 vehicles built by the L.M.S.R. for the Liverpool—Southport line. Each of the 59 motor-coaches in this order has four nose-suspended motors with individual one-hour ratings of 235 h.p., and the vehicles are capable of a top speed of 70 m.p.h. Work for the Southern Railway included the motors and train equipments of the stock introduced coincidently with the electrification extension to Gillingham and Maidstone at the beginning of July, and also the complete cars—12 motor-coaches and 14 trailers—for the Waterloo & City line. All-welded steel construction is being used for the latter. The principal export order was the electrical equipment for 12 motor-coaches and 20 driving trailers for the 1,500-volt d.c. Capetown suburban system of the South African Railways, which was provided with English Electric rolling stock equipment when first electrified nearly 15 years ago.

General Electric

Electrical equipment is being constructed for eight three-car trains to run on the Manchester—Sheffield—Wath section of the L.N.E.R., and many interesting features have had to be considered in the design of this equipment, which will be installed in the first multiple-unit trains in England to work on a 1,500-volt line in conjunction with locomotives capable of heavy regeneration. Other important contracts include over 1,400 railway motors for the tube and surface lines of the L.P.T.B., field shunting equipment for 55 Metropolitan line coaches for the same system, and auxiliary equipment for eight non-driving trailer coaches for the joint L.M.S.R.-L.N.E.R. Manchester—Altrincham railway.

One section of a contract for air-cooled rectifier equipments for London Transport includes oil circuit-breakers for protecting the transformers feeding the rectifiers. For this service, the utmost rapidity of operation is necessary in order to cut off the supply to the rectifier in the event of a back-fire. A breaker has therefore been evolved which, although following conventional design, gives operation at least as rapid as that obtainable from breakers to which the description " high speed " is specifically given. Lightness of moving parts contributes greatly to the result achieved. This breaker is rated at 500 MVA, 22 kV.

A further part of the same contract for an air-cooled rectifier plant comprised 22 static 22 kV transformers, each to feed a twin set of 12-phase rectifiers. The connections and winding arrangement have been designed to ensure equal division of load between the 24 anodes involved, and, in addition, phase-displacing windings are included on the h.t. side to enable two equipments to be operated in parallel as an effective 24-phase combination if required.

Electric Railway Traction

Brazilian Railway Electrification

DURING the course of January numerous reports appeared in the press that American interests had organised an Electrical Export Organisation to handle an electrification project in Brazil, said to be the completion of the conversion on the Central of Brazil Railway. It will be remembered that the electrification of this line was entrusted some years ago to Metro-Vick on the understanding that that company would complete the work in two stages, first the inner and outer suburban area of Rio de Janeiro extending to Nova Iguassú and Bangú, and secondly the main lines to Santa Cruz and Barra do Pirahy. The first portion has been operating satisfactorily for over a year, successive sections being turned over to electric traction between July, 1937, and February, 1938; a comprehensive description of the equipment was published in the issue of this Supplement for March 4, 1938. It was always intended that the main-line conversion should follow some time after the completion of the suburban system, and actually the whole work was to be covered by two separate contracts between the Brazilian Government and Metro-Vick. That American interests should endeavour to step in on the second part would not be surprising, for it does not appear unlikely that one of the principal objects of the present war is to concentrate in the hands of Wall Street finance a much greater share in the creation of foreign credits than it has had hitherto. Fortunately, in this case the reports appear to be quite untrue; Metro-Vick informs us that the arrangements for the completion of the second portion are now under discussion between that company, the Department of Overseas Trade, and the Central Railway of Brazil, and that there is no reason to expect that the second stage will not be carried out by the English company. Nevertheless, we believe that the British Government's handling of the general financial and economic situation, particularly its disregard of the growing inflation, is not such as to put any British firm in a strong position to complete any type of contract. It is not unlikely that the primary object of the Electrical Export Corporation said to have been formed by leading American manufacturers is to obtain the contract for the conversion of a section of the Sorocabana Railway, a strong bid for which was being made by English makers until the war turned Brazilian trade into a gift for America. Such an organisation could easily handle any other contract put in its way as a result of British official policy.

The Sorocabana Conversion Project

AS we noted in the December 8 issue of this Supplement, the Brazilian Government has authorised the conversion to 3,000-volt d.c. traction of the 87-mile metre-gauge main line of the Sorocabana Railway between São Paulo and São Antonio. Proposals to electrify this line were made as long ago as 1924, but the project has been shelved from time to time, and it might not be a bad thing if it were shelved again for a time; such a delay would certainly be of benefit to English trade, for manufacturers in this country are known to have been in a strong position regarding the contract until the beginning of the war, and the Brazilians themselves will hardly get the best results from a conversion which is likely to be saddled with heavier initial cost than usual. This particular line is laid generally with 90-lb. rails, and has several 1 in 50 grades over which regenerative braking would be used. Both multiple-unit trains and locomotives would be necessary, and power would be obtained from the three-phase 88-kV network of the São Paulo Light & Power Company. Conversion to 3,000 volts d.c. would be effected in mercury arc rectifier substations, but, as is understandable, no definite conditions have been laid down in the specification as to the use of inverted rectifiers. The 3,000-volt d.c. system may be regarded as the Brazilian standard, and at the moment is represented by the Paulista Railway's electrified main line and the Rio inner and outer suburban system of the Central Railway, both broad-gauge lines.

The New L.M.S.R. Electric Stock

THE 152 new electric vehicles for the services of the Liverpool—Southport electrified lines of the L.M.S.R. (which include the branches to Ormskirk and Crossens) have some interesting features. In the first place they operate over one of the earliest steam railways to be electrified, and replace stock 30 to 36 years old which was noteworthy in being 10 ft. wide overall, the old Lancashire & Yorkshire Railway having taken full advantage of the wide loading gauge over these few miles of line to provide maximum carrying capacity. Moreover they form a reversion to the old open saloon interiors which were used in the original trains, but which for a few trains built ten or a dozen years ago were given up in favour of compartment stock similar to the most recent L.M.S.R. London—Watford trains. Except for the stock introduced when the L.M.S.R. electrified the Wirral lines in 1938, this new stock, which is an advance on that built for the Wirral, comprises the first all-steel welded coaches to be used in England, and the construction marks a principal stage in the evolution of coaching stock design on the L.M.S.R. Some years ago the standard stock consisted of a separate riveted steel underframe and a timber-framed body with steel outer panels, but to reduce weight without sacrifice of strength, welding and high-tensile copper-bearing steel have been used increasingly, and the use of timber gradually reduced. This evolution was described in a paper by Mr. W. A. Stanier, prepared for presentation to the joint meeting of the British and American Mechanical Engineers at New York last September. The outbreak of war necessitated the abandonment of this meeting, but part of the paper was summarised, with illustrations, in THE RAILWAY GAZETTE of December 22 last (pp. 806-811). These new electric coaches, fully described in the following pages, embody the first attempt in England to use the Vierendeel girder as the basis of the body frame design. The electrical equipment is no less modern than the mechanical design, and provides good power-weight ratios, normal working accelerations fully up to present day averages, and gives, for what is essentially suburban stock, the high top speed of 70 m.p.h. The up-to-date features of the design also cover the provision of pneumatically-operated sliding doors, roller bearings for axleboxes and traction motor armatures, and special ventilating arrangements for the car and motors.

NEW TRAINS FOR THE LIVERPOOL–SOUTHPORT LINE

Over 150 welded steel vehicles, with electrical equipment valued at quarter of a million pounds, will completely revolutionise travel and operation on one of the earliest English electrified lines

ALTHOUGH additions have been made to the rolling stock used on the electrified Liverpool—Southport line of the L.M.S.R. since the conversion by the erstwhile Lancashire & Yorkshire Railway in **1904-10**, many of the vehicles were some **36** years old, and about two years ago a complete replacement programme was put in hand. The work comprised the building of **152** coaches made up into **34** three-coach trains consisting of a motor-coach, trailer, and driving trailer, and **25** two-coach units consisting of a motor-coach and a trailer. Of the two-car trains **16** have third-class trailers and nine have composite trailers. The two-coach units have a driving position in the motor-coach only and are used in conjunction with triple-car trains to form trains of five coaches during the rush hours, when some six-coach trains are also in service. The non-driving ends of the two-coach units are provided with a window and bell communication with the driver's cab in the motor-coach to facilitate shunting and the making-up of trains for service. The use of two-car and three-car sets makes possible trains of any coach number from two upwards.

Performance

The normal service is provided by trains stopping at all intermediate stations with an average distance between stations of **1·23** miles. A schedule speed of about **30** m.p.h. will be maintained with a fully-loaded train, allowing for a **20**-sec. stop at each intermediate station. This represents a considerable advance on the present timing, amounting to about a **10** per cent. reduction in overall running time. The initial acceleration from rest is approximately **1·6** and **1·4** m.p.h.p.s. respectively with fully-loaded five-coach and six-coach trains. In addition to the normal stopping service a number of through trains are to be provided, and with this in view all trains are capable of a maximum speed, fully loaded, of **70** m.p.h.

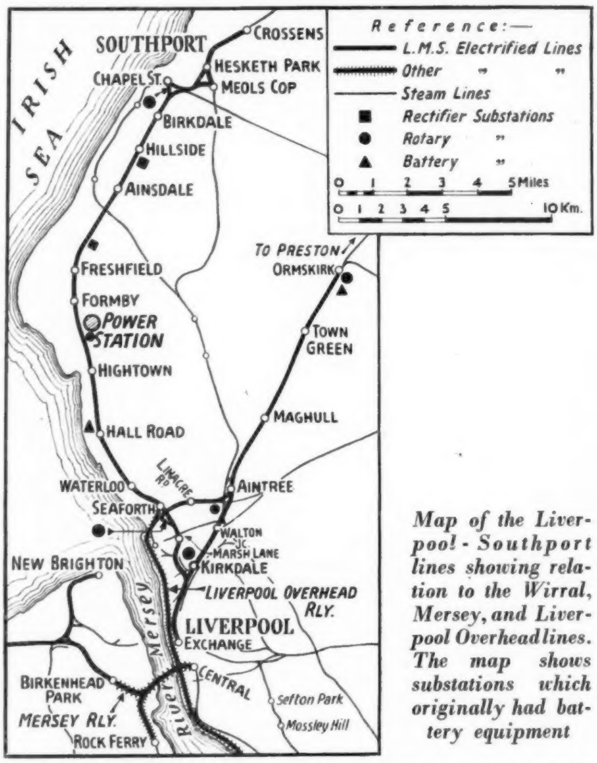
Electrical Equipment

The electrical equipment throughout was made by the English Electric Co. Ltd. to the requirements of Mr. C. E. Fairburn, Deputy Chief Mechanical Engineer and Electrical Engineer, L.M.S.R. The equipment on each motor-coach consists of two identical but separate control equipments arranged to give series-parallel and field-tap control of a pair of motors with bridge transition from series to parallel. The tap-field connections are only available when the motors are in parallel after all the accelerating resistance has been cut out.

Each two-motor equipment consists of **19** electro-pneumatic contactors which arrange the motors in series or parallel and cut out starting resistance as the motors accelerate. Two of these contactors are fitted with extended arc chutes and act as line switches. The contactor is capable of working over a wide range of current, for although the normal accelerating current is only about **460** amp. per motor the contactor has been tested as a line switch up to current of over **11,000** amp. on a **600**-volt inductive circuit.

The power supply for each equipment is derived from the power bus line which is continuous throughout any train, and is fed directly by third rail collector shoes on the motor-coaches and driving trailers. Each two-motor equipment is connected to the power bus line through its own isolating switch and fuse, mounted on the underframe. The circuit then divides, one half including an overload relay and line contactor **LS.1**, and the other half an overload relay and line contactor **LS.2**; the circuits then each pass through a motor and its associated bank of resistances and contactors to the running rail return. The two halves of the circuit are interconnected by contactors to provide for series operation. (See p. **12**.)

A step of resistance is connected between the two halves of the circuit on the motor side of the line contactors LS.1 and LS.2; this acts as an additional resistance on the shunting notch and also as a limiting resistance in

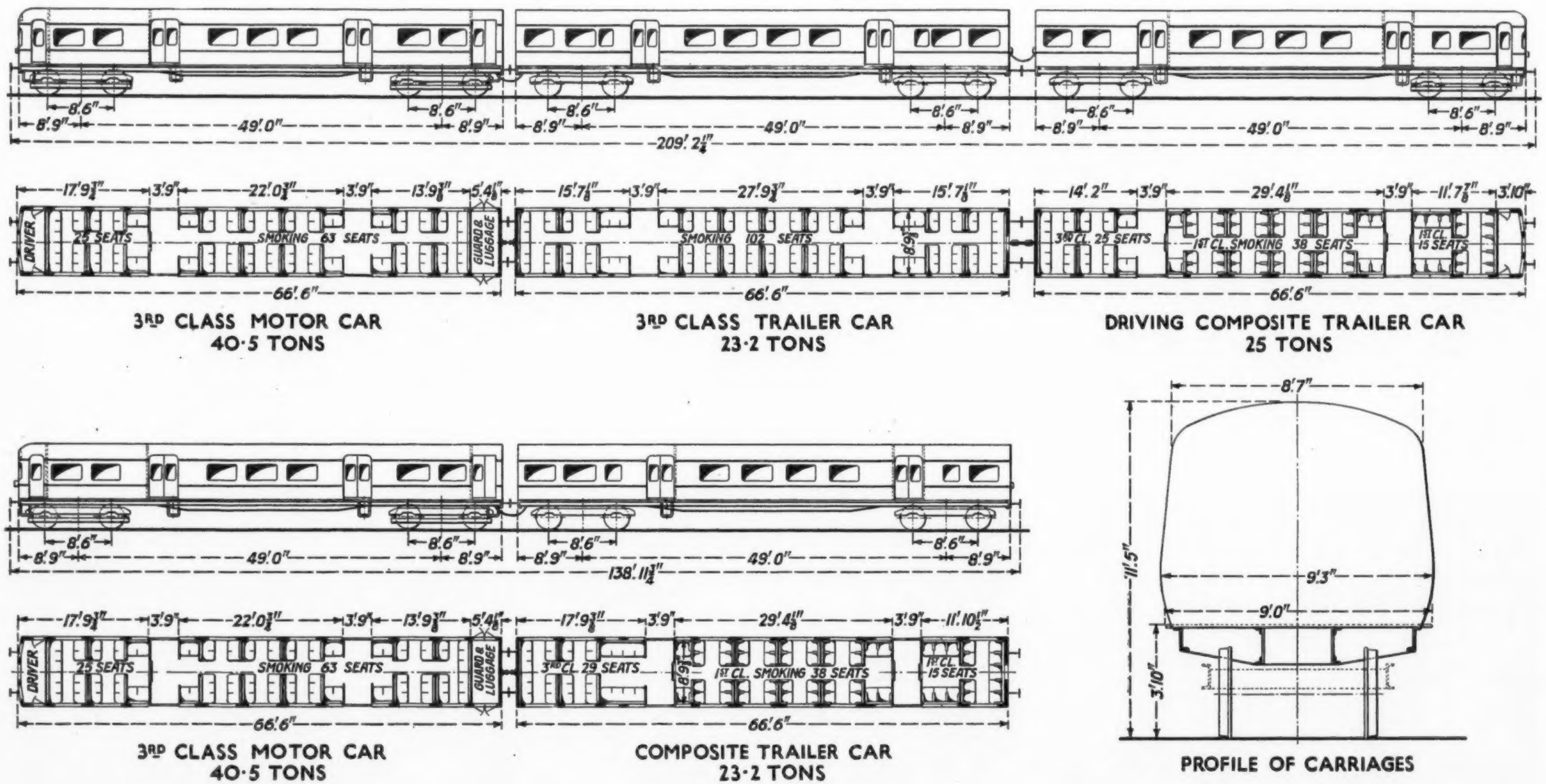


Map of the Liverpool-Southport lines showing relation to the Wirral, Mersey, and Liverpool Overhead lines. The map shows substations which originally had battery equipment

case of overload. An excessive current in either motor operates the overload relay which is in series with it, and this causes the associated line contactor, LS.1 in the case of No. 1 motor, LS.2 in the case of No. 2 motor, to open. Whichever line contactor opens first causes the other line contactor to open immediately afterwards by means of interlock contacts. In this way, the line contactors always open in sequence on an overload, the first one opening across the limiting resistance and putting that additional resistance in circuit, and the second opening in series with the limiting resistance.

Traction Motors

Four nose-suspended traction motors are provided on each motor-coach, and drive their respective axles through spur gearing with a **17 : 64** gear ratio. The one-hour rating is **235** h.p., **340** amp. at **580** volts, and the continuous rating is **184** h.p., **265** amp. at **580** volts. The



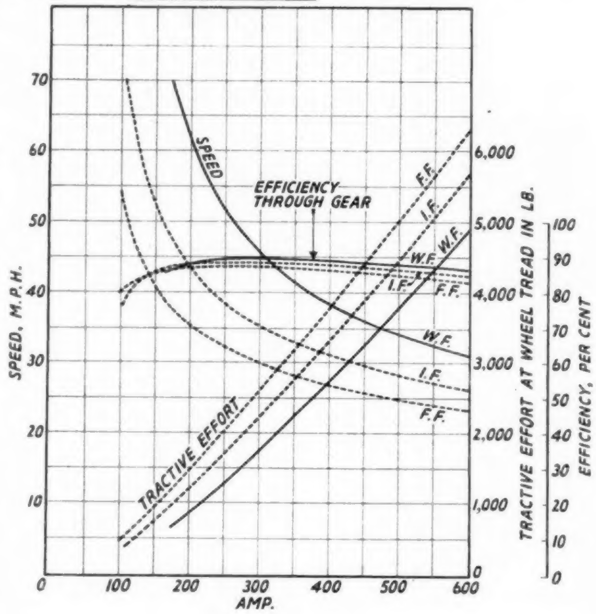
General and seating arrangement diagrams of the three-car and two-car all-steel welded multiple-unit trains built at the Derby works of the L.M.S.R. in 1939 for the Liverpool-Southport 600-volt d.c. electrified lines. Each formation contains one four-motor motor-coach with a one-hour capacity of 940 h.p. English Electric power and control equipment is installed. The stock has a maximum body width of 9 ft. 3 in. compared with the 10-ft. straight-sided stock used for the past 36 years, and the tare weight is equal to a little over 1,000 lb. a seat in the motor-coaches, and to about 510 lb. a seat in the trailers. The maximum speed of a fully-laden train along the level is 70 m.p.h.

traction motor has been designed to obtain the smallest size and weight for output consistent with satisfactory operation at high speed, at the same time retaining a sturdy and robust construction. To obtain good commutation at the relatively high output and speed at which this motor has to operate, a multiple armature winding has been adopted with equalising connections. A series field is provided tapped at approximately 70 and 43 per cent. of the full field value. The result of this is a motor which is outstanding for its power weight ratio, the weight complete with gear case, gear wheel and pinion of 4,484 lb. giving a ratio of 19·1 lb. per h.p.

In order to ensure that the motors are ventilated with clean air, arrangements have been made to draw the ventilating air through louvres placed on the roof of the coach, the air being taken by ducting and flexible bellows to the air inlet on the motors. It is anticipated that this arrangement will result in the elimination of dirt and brake dust inside the motor, and in addition to reducing the amount of maintenance necessary should tend to give a reduction in brush wear and freedom from sticking brushes. Roller armature bearings are used and the suspension bearings are of the normal sleeve type.

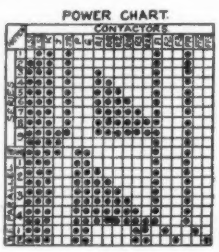
RATINGS	ONE HOUR	CONTINUOUS
TEMP. RISE °C.	120 BY RES.	105 BY RES.
OUTPUT, H.P.	235	184
AMP.	340	265
VOLTS	580	580

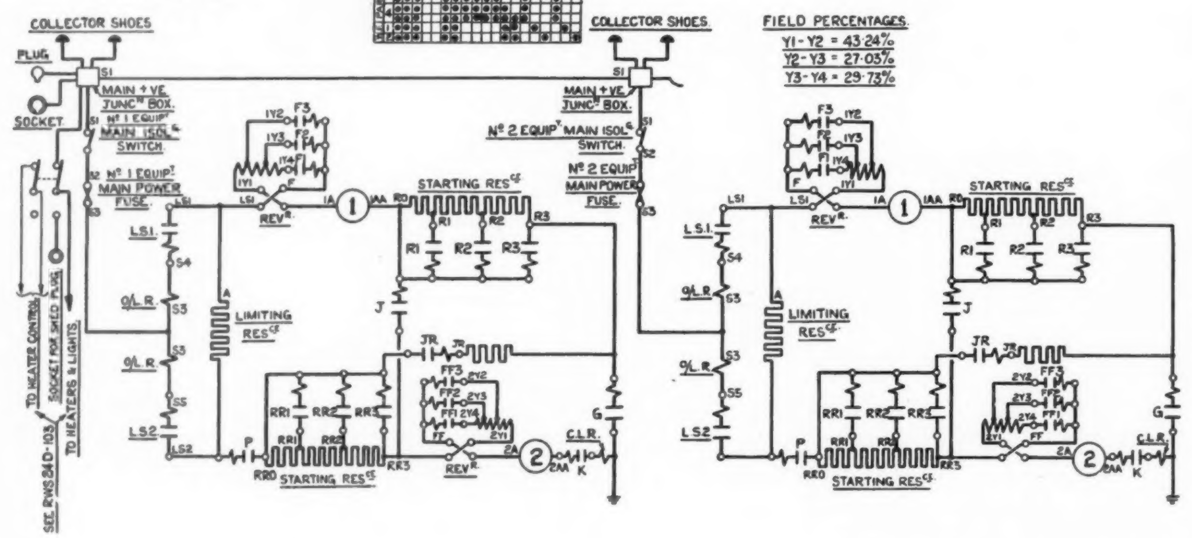
WHEEL DIAM. 36″
GEAR RATIO 64 / 17 = 3·76
ARM R.P.M. = MILES PER HOUR X 35·2



Far right: Characteristic curves of English Electric 235 h.p. traction motor

Below: Diagram of main circuits, new Liverpool-Southport electric trains





Control

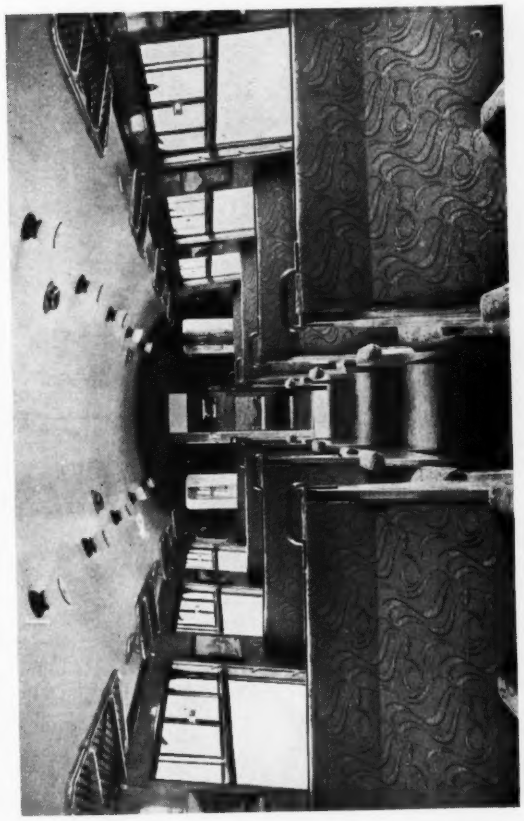
The electro-pneumatic contactors for each equipment are carried in two cases and the electro-pneumatic reverser in a third, making three main cases for each of the two equipments on a motor-coach. The overload relays and the accelerating relays are housed in extensions at the ends of the contactor cases. These main cases, together with the motor-generator set, battery, main resistances of the unbreakable type, compressor, main equipment fuses and equipment isolating switches are all mounted on the underframe, which, being of the centre longitude type without a deep truss extension, allows good access to the cases from below the underframe and coach side panels.

Attention has been given to making the equipment as accessible as possible and to provide for ease of maintenance; important among these provisions are the method of mounting the main cases and the arrangement of the contactors. The main cases are carried on lateral bearers of angle or inverted T section welded to the underframe, and to remove them bodily from the coach it is only necessary to remove the retaining bolts, lift the cases slightly on a special lifting truck, and withdraw the truck sideways. In this way a complete case can be changed in a short time, thereby enabling a coach to remain in service almost continuously and limiting stoppages for maintenance to an absolute minimum.

A departure from the normal contactor arrangement has been introduced in that both the main contacts and the interlock contacts are at the front of the contactor, and provision is made by means of a lever for operating the

One of the three-car 940 b.h.p. welded steel multiple-unit trains for the Liverpool-Southport routes

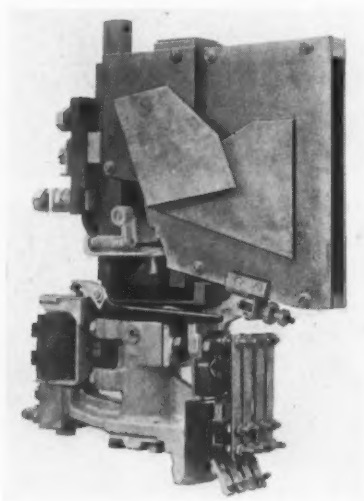
Interior of third class trailer car; the seat frames are formed of welded steel pressings with a wood covering at the side



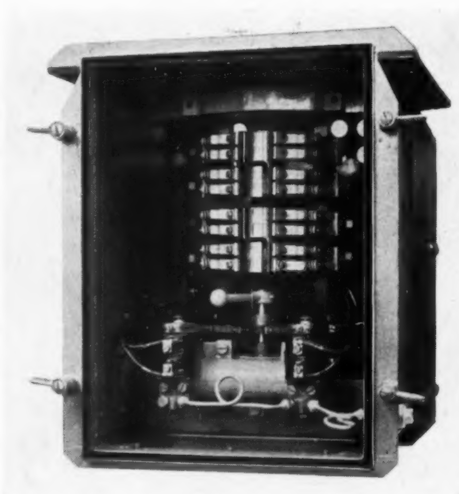
Interior of first class composite driving trailer; the seats here are two a side, in place of three and two in the third class saloons

Note accessibility of the electrical switchgear housed below the underframe

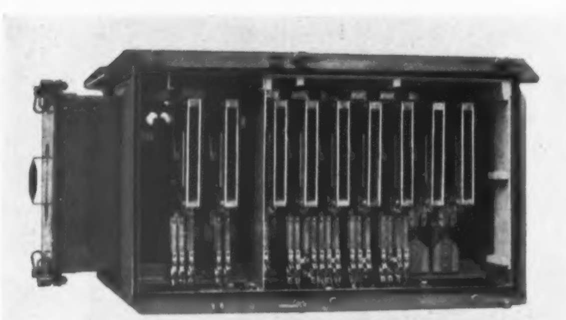
Interior of the motorman's cab



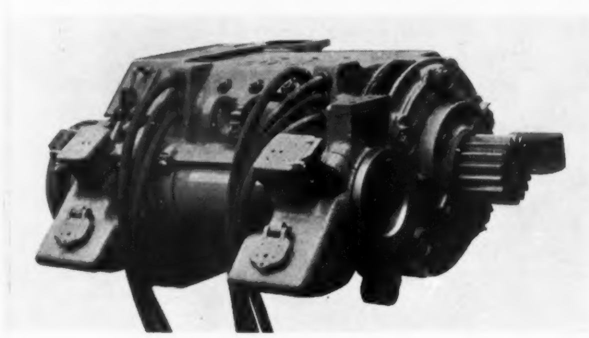
Electro-pneumatic contactor



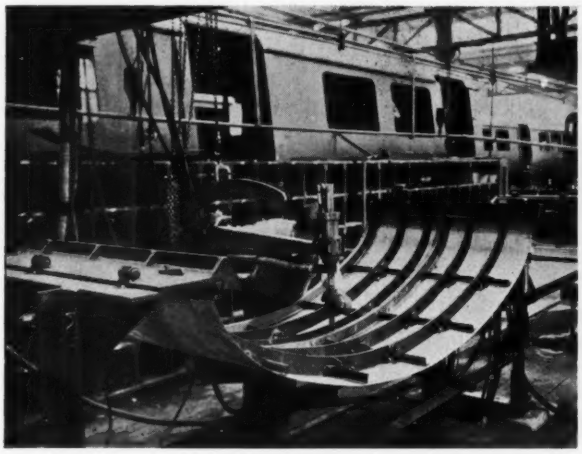
Reverser unit



Assembly of line switch, contactor and overloads housed in a single case

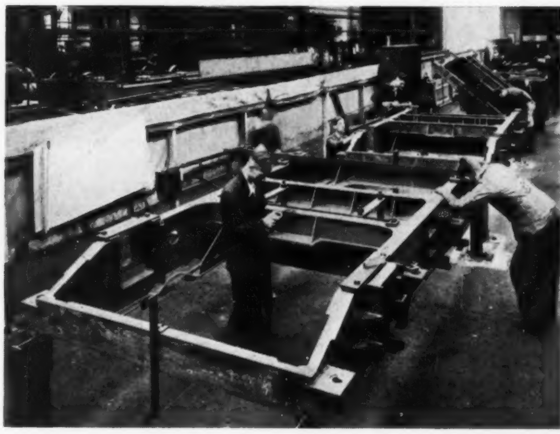


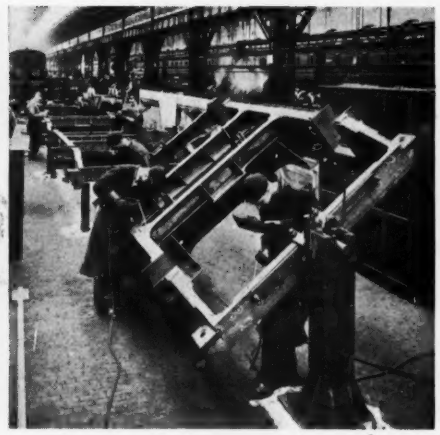
English Electric 600-volt traction motor with a one-hour rating of 235 h.p.



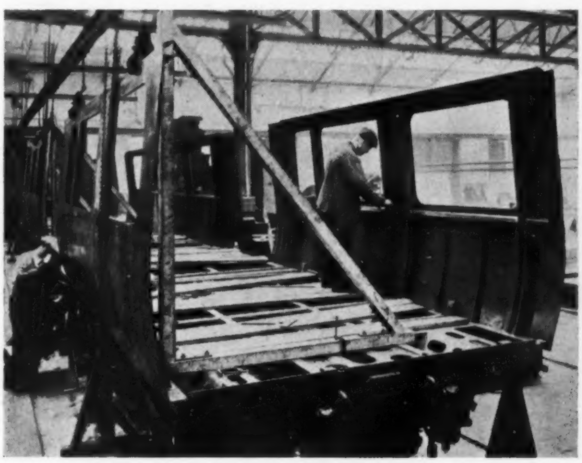
Building up one of the welded steel roof sections on its jig; the panel has already been pressed to form a rain gutter

A side frame being assembled for its full length; a separate jig is used for each side; the panels are spot-welded to the frame

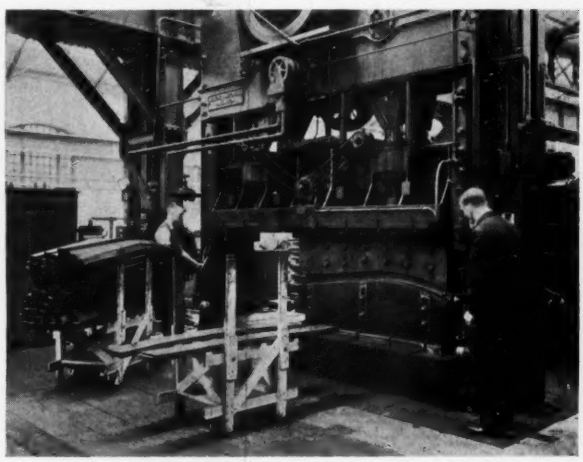




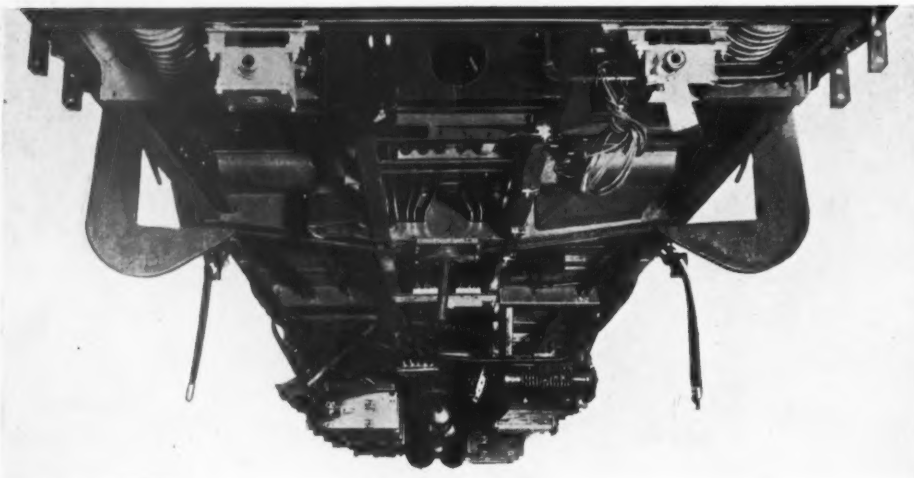
Two views of the bogie frame structures of the new Liverpool-Southport electric rolling stock being welded and lined up on plain and rotary jigs at Derby carriage works, L.M.S.R.



Assembling the completely welded body sides on the completely welded 66-ft. underframe

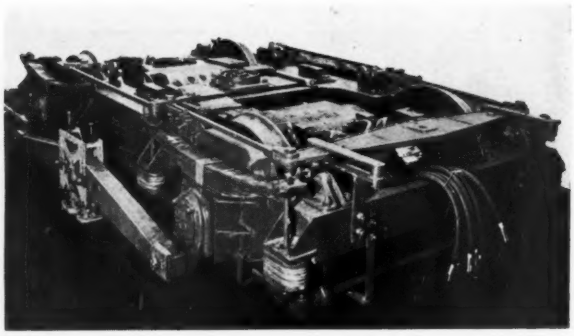


The 300-ton press used for the carlines, body pillars and other frame sections



View showing the location of the electrical equipment, air brake equipment, cables and conduit below the welded steel underframes of the new Liverpool-Southport trains

General view of swing-bolster trailer bogie with roller bearing axleboxes and welded steel frames



Driving bogie with framework of welded high-tensile steel and powered by two 235 h.p. motors

The present lighting of the new stock for the Liverpool-Southport routes is in accordance with war-time regulations, but particular care has been taken to give adequate reading light to as many passengers as possible

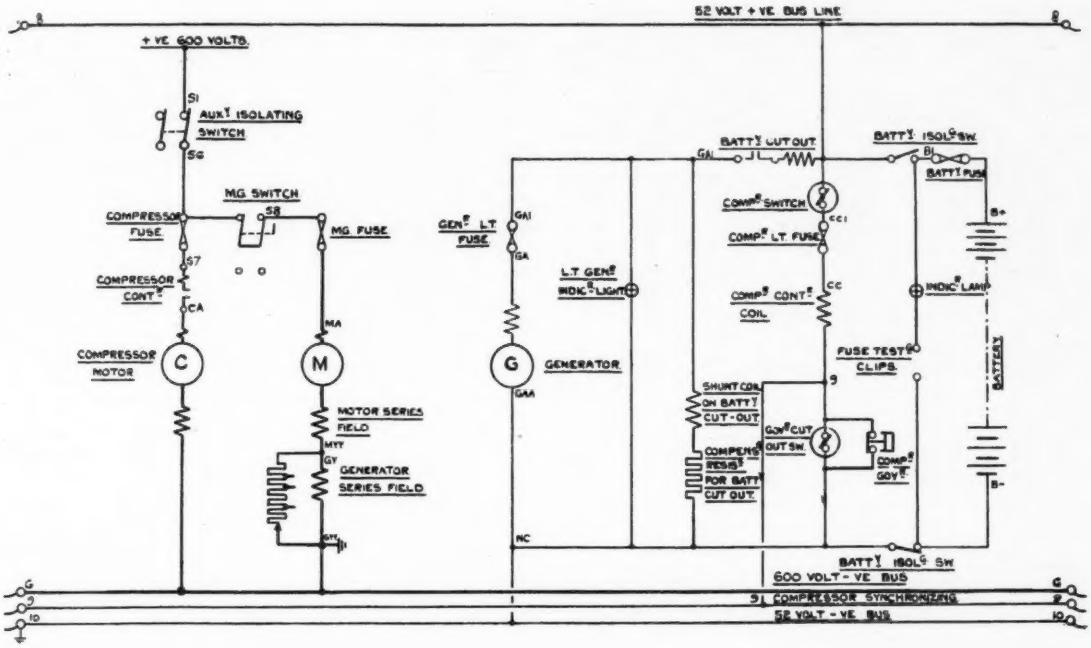


Diagram of auxiliary circuits of the new electric trains for the Liverpool-Southport services, L.M.S.R.

magnet valve from the front of the contactor by hand, so that all normal maintenance can be carried out from the front of the contactor case. All cases have front and back dust-tight covers held in position by spring catches which can readily be removed for inspection.

The electrical equipment in the motor-coach driving cab is grouped into three assemblies, the auxiliary cupboard, master-controller assembly and control connection box, which tends to present a clean cab layout and simplifies the conduit and wiring runs. The auxiliary cupboard contains both a high-tension and a low-tension panel on which are mounted the fuses for the auxiliary circuits, lighting, heating and compressor contactors, together with the switches controlling the auxiliaries. A colour code system is used for the fuses so that it can be seen at a glance that any fuse holder contains the correct fuse.

The l.t. supply for the control circuits is provided at 52 volts by a motor-generator set in conjunction with an alkaline battery of 36 cells. The characteristics are such that a voltage regulator is rendered unnecessary. The motor-generator starting switch is operated by a removable key which can only be withdrawn when the switch is open, thus making it impossible to run two motor-generator sets in parallel on a train containing two motor-coaches. The batteries normally work in parallel and are kept fully charged by whichever set is running.

Acceleration of the motors is controlled by a balanced armature type of current limit relay which is a considerable advance on the normal plunger type in that it is not affected by vibration or train movement. In order to obtain the maximum overall acceleration from standstill to weak field connection which the adhesive weight will allow, and at the same time avoid excessive peak currents in parallel, the minimum current at which the relay operates is higher during series notching than during parallel notching.

It has been indicated above that the power supply to a defective pair of motors can be cut off by a manually-operated equipment isolating switch, but in addition provision is also made to isolate any control equipment by push button switches in the drivers' cabs actuating control cut-out relays. Any two-motor equipment in any train up to six cars can be cut out by means of the appropriate push button in any driver's cab.

Auxiliaries

Compressed air for the brakes, electro-pneumatic control gear, and air-operated doors is provided by a two-cylinder air compressor driven direct without gearing. The compressor motor is controlled by a 600-volt electro-magnetic contactor, the 52-volt operating coil of which is in series with the compressor governor contacts. A synchronising wire ensures that the compressors operate simultaneously when two motor-coaches are employed.

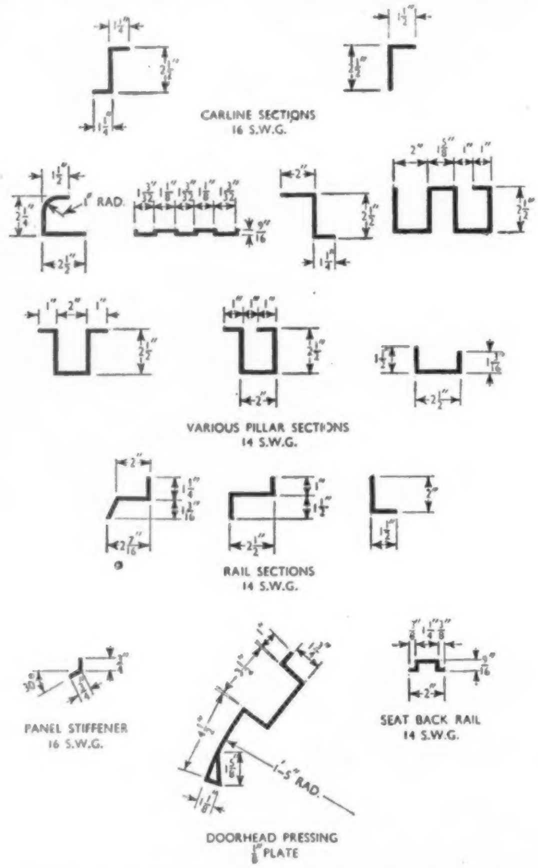
Coach lighting is provided by circuits of five 60-watt lamps in series connected to a 600-volt busline which is fed through an electro-magnetic latch type contactor operated by a set-and-trip switch in the guard's van which controls the whole of the coach lights in any train. All lighting is by means of 60-watt lamps burning five lamps in series on the 600-volt supply. White opal glass reflectors, held in hinged galleries, serve to shade and reflect the light. The light fittings are moulded in black bakelite material and are attached directly to the conduit boxes. For train marking purposes, four headlights are provided on the driving ends of the motor car and driving trailer, the code selection being made by turning the headlight reflector through 180° by means of a handle accessible from within the driving compartment. One headlamp of each group has provision for the reception of a slide of ruby glass which can be used as a tail lamp in addition to the normal oil lamp. Destination indicators are recessed into the face of the driving compartments. The coach heaters are connected to a heating busline and the heating contactor is controlled by a thermostat placed in the motor-coach saloon.

Construction of Mechanical Portion

The rolling stock itself was built at Derby works to the requirements of Mr. W. A. Stanier, the Chief Mechanical Engineer, and in order to achieve the dual aim of light weight and rigidity the whole body structure from under-

frame to roof is formed as one girder, of practically complete welded construction, the only riveted joints being in cross panels at the inner ends of the cars and at the guard's compartment. This construction represents the latest development in L.M.S.R. coaching stock practice, timber-framed bodies mounted on steel underframes having hitherto been standard. At Derby works a new system of unit assembly was evolved under the direction of the Carriage Works Superintendent, Mr. E. Pugson, in order to maintain the desired delivery of three cars a week from shops engaged at the same time and to a greater degree in the construction and repair of ordinary coaches.

A large number of pressings and special sections are incorporated in the body framing, some of which are shown in an accompanying illustration. The steel sheet



Some of the special body-frame sections used in the welded steel Liverpool-Southport trains

for these parts is required to be suitable for deep drawing or pressing, double-pickled and oiled. The original tensile strength of the steel is 28-32 tons per sq. in., which, after annealing, becomes 24-26 tons, a figure which is increased slightly after pressing. The Z sections for the carlines are pressed first as a flanged channel or top-hat section, and after being set in a 60-ton press with timber blocks to correct any distortion from the main 300-ton press, are slit down the centre to form the Z members. The special works equipment introduced for these Liverpool—Southport cars, and for adaptation to the needs of future ordinary coaches, comprise a 300-ton press driven by a 30-h.p. motor and used for the carlines, body pillars, door pillars and the like; a 50-ton press brake dealing with the partition channels, Z sections, and the turning of the edges of special body pillars; two 2 ft. 6 in. open-fronted presses of 60 tons capacity; an 18-in. saw; two guillotines for sheets up to 11 ft. wide; and three 6-ton bench presses.

The body is first built up of unit assemblies consisting of the sides, roof, coach ends, cross partitions, and internal draught screens, all of which are fabricated on jigs of their own by special electric resistance spot welding machines kept to the particular operation. Three roofs can be turned out in a week from the one roof jig and for the side framing there is a separate jig for each side. The side panels are of 16 s.w.g. steel and the joints are welded in an automatic carbon arc machine; the composition of the panel sheet steel, which is hydraulically flattened and specially prepared for painting, is:

Carbon	0·07–0·08 per cent.
Silicon	Trace
Manganese	0·34–0·39 per cent.
Sulphur	0·039–0·046 per cent.
Phosphorus	0·01 per cent.

To facilitate the spot welding of the sides to the framing it is necessary for the whole of the panels on each side to be made in one piece. The nose of the leading end of the motor-coach is built up in sections from panels which have been suitably curved on a panel-stretching machine. As the number of motor-coach outer ends required was comparatively small, the jig framework was made of timber instead of steel in order to reduce the cost. The roof is built up in its jig as one complete unit from separate galvanised steel panels.

Bogie Frame and Underframe Construction

Bogie frames and underframes are also welded up on jigs, and to cover the four types of underframe and their fabrication in correct train order, a special jig was constructed to locate all the members of the four types. Broadly the fabrication of the underframe is split up into two operations: (*a*) the construction of the centre longitudinals as a box girder, on a separate jig; (*b*) complete assembly of underframe. A high-tensile chromium-copper steel has been used for the underframes and bogie frames and has required special attention during welding. The analysis is:

Carbon	0·20 per cent. max.
Silicon	0·30 ,, ,, ,,
Manganese	1·40 to 1·60 per cent.
Sulphur	0·06 per cent. max.
Phosphorus	0·06 ,, ,, ,,
Chromium	0.10 ,, ,, ,,
Copper	0·60 ,, ,, ,,

The ultimate tensile strength of this steel is 37 tons per sq. in., the yield point 23 tons per sq. in., and the elongation on 8 in. a minimum of 18 per cent. A cold bend test is specified, in which the B.S. test piece must be doubled over, without fracture, to an internal radius 1½ times the thickness of the test piece.

In each motor-coach underframe there are about 1,700 ft. of welding, and in a trailer underframe 1,420 ft., consisting chiefly of a.c. fillet welds of ¼-in. leg length. The amount of welding per bogie is approximately 750 ft.

Body Design

The Vierendeel truss arrangement comprises a simplified form of rigid frame incorporating parallel top and bottom booms and a number of vertical columns rigidly connected to the booms, which transmit bending forces, as well as tension, compression and shear. In this particular application, the bottom boom (underframe) and top boom (roof structure) are not equal in section or moment of inertia as they would be in a true Vierendeel girder; further, the pillars are curved, as the cars are wider at

the waist than at floor or cantrail level. This curvature increases the tension and compression forces in the columns, and the bending at the top and bottom is accompanied by some twisting. Actually, the individual pillars comprise two pillar members placed close together as can be seen in some of the accompanying illustrations. An analysis of the forces and stresses found in the complete frame structure was given by Mr. Stanier in his paper "Lightweight Passenger Rolling Stock" prepared for the abandoned joint summer meeting of the Institution of Mechanical Engineers and the American Society of Mechanical Engineers in New York last year.

The interior partitions and draught screens of the coaches are fabricated from light pressed steel framing members arc-welded together and covered with steel sheet. The partitions which extend from side to side of the body are fabricated by riveting, while the draught screens and sliding door partitions at the lobbies are spot welded together. To prevent corrosion of the interior surfaces of steel body side and roof panels, spaces have been left open at the bottom of the body side and at the gutters, so that there may be as little difference as possible in temperature and humidity between the air in contact with the outer and inner surfaces of the panels. This result is further sought by the provision of a number of roof extractor ventilators communicating only with the space between the outer and inner roof panels.

Body Interior

Access to the interiors of the cars is obtained by 3 ft. 9 in. doorways leading into the lobbies. These doorways are closed by double doors which slide back into the body side walls. The doors, which are Alpax castings, are air-operated, the control being in the hands of the guard. Push buttons are provided on the doors by means of which the passengers may open the doors themselves if the guard has previously pressed a master button in his control box. The opening and closing of each door operates an interlock switch which permits the driver's signal bell being sounded by the guard only when all the doors are properly closed.

The interior finish of body sides and ends in the third-class compartments is composed of plywood panels veneered with Sapelle or Paldao, and the seat ends are in laminated block-board veneered to match. The transverse seats are arranged on each side of a gangway to seat three persons abreast on one side and two on the other, and are upholstered in green uncut moquette. The seats are supported on fixed frames fabricated by welding from light steel pressings. Electric heaters are positioned below the seats. The floors are covered with linoleum laid on felt and cork, which are supported by galvanised steel dovetail sheeting laid across the underframe and welded to it.

In the first-class campartments, arm rests are provided in the seats, which are upholstered in fawn and brown uncut moquette, and a mottled carpet to tone is laid on the linoleum floor covering. The body side finish is in Betula veneered plywood. Photographs are provided on the walls of first-class compartments, their place being taken by advertisement frames in the third class.

The windows are provided in their upper halves with sliding light ventilators, and the interior metal work of these is finished in bright nickel. Grab rails, commode handles and brackets for ceiling grab straps are in aluminium alloy castings and steel tubes covered with Doverite, Resistoid, or Firmoid finishes coloured to tone with the veneers.

The driver's cabs are not provided with interior finishing panels to either the body end, sides, or roof, but the inner surfaces of the outer panels are sprayed with Roberts's asbestos to afford the driver some protection from excessive heat. An air-operated wind-screen wiper is mounted over the left-hand window. Driving is normally carried on in a sitting position, and an adjustable upholstered seat is provided which automatically swings out of the way when not in use.

Bogies

The bogies are developments of L.M.S.R. standard carriage bogie design. The driving bogies are of the plate frame type with 36-in. wheels spread over a base of 8 ft. 6 in. Each carries two traction motors with rubber nose suspension springs housed on an extension of the centre transom. In both types of bogie special attention was given to the design and fabrication of the joints between the centre transoms and the side frames, and the gussets were designed to reduce stress concentration at corners while at the same time leaving the joints strong and flexible. The gussets are not butt welded to the members, but overlap them, this method having been found to produce a more reliable joint; the free edges are curved to reduce rigidity. Compared with the old Liverpool—Southport stock, a saving in the unsprung weight has been effected by using tyred disc wheels of 36 in. diameter instead of 43½ in. The welded steel box-form swing bolsters are supported on double helical (concentric) springs at each side.

Roller Bearings

Skefko roller bearing axleboxes are used for the trailer bogies; some are of the double-bearing double-row self-aligning type, and others have parallel rollers with the end thrust taken by a bronze pad mounted on the axlebox end cover.

Timken tapered roller bearings are used in the driving bogie axleboxes, and both the cast steel boxes and guards are fitted with manganese steel liners. The double inner race of the bearing is a heavy press fit on the axle end, the inner face taking its abutment against a steel ring which in turn abuts against the shoulder on the axle. The outer races of the bearings are a close fit in the bore of the axlebox, and the bearing is adjusted by means of shims placed under the flange of the inner cover of the box. The bearing is removed from the axle by pressure applied to the abutment ring after the box has been removed, a two-piece device being used for this purpose. The bearings run in an oil bath, and the lubricant used is a highly refined neutral mineral steam cylinder oil. The box is designed to hold a quantity of oil usually sufficient for six months' operation without replenishment. Cored passages are provided in the box, which allows of a self-circulatory movement of the oil, set up due to the tapered construction of the bearings.

This type of Timken bearing and axlebox has been evolved to provide an assembly which can be swung in modern collet type wheel lathes. The bearing outer races are fitted loose in the axlebox body and when the cover nuts have been removed the body can be withdrawn by hand complete from the bearing assembly, bringing with it the front outer race and the front roller and cage assembly. The dual inner race tapered roller bearing differs from the standard Timken railway bearing in that the small ribs or raised circular ridges at the outer ends of the inner race have been deleted and the rollers are contained in a special cage. This construction allows the self-contained roller and cage assemblies to be removed bodily from the inner races when the outer races are moved aside.

When tyres require turning bronze protective castings are fitted over the back bearing assemblies, and the wheel lathe collets are fitted over the front inner race tracks. The lathe collets are made of a relatively soft material to

prevent the inner race tracks from being damaged, and the bronze casings protect the back bearings from swarf and damage during tyre turning. After fitting of the protective casings and collets the wheel set is swung in a collet type tyre turning lathe, the collets being held in conical housings in the lathe headstocks.

Brakes and Miscellaneous Equipment

Westinghouse electro-pneumatic braking is incorporated. The driver is provided with a self-lapping type of brake controller and a gauge is mounted in each cab to indicate the pressure in the brake cylinder of the car in which it is mounted. This assists the driver to estimate the power of any brake application throughout the train. Cast-iron blocks are used on the motor bogies, but Ferodo blocks on the trailer bogies. Provision is made for readily altering the leverage of the brake rigging on all cars if it is desired to change from cast iron to Ferodo blocks or *vice versa*. Both types of bogie have two blocks per wheel applied by clasp rigging from cylinders mounted on the car underframe. The primary brake cross rods on each bogie are built up by welding.

The buffing and drawgear follow L.M.S.R. standard practice. There are side buffers and screw couplings to all cars at both close-coupled and wide-coupled ends. The only departure from standard practice is in the point of draw, which in this stock is just behind the headstock (strengthened for the purpose) instead of at the main transoms over the bogie centres as is more usual.

* * * *

As a war-time measure, the trains have been turned out of the shops equipped to meet the lighting regulations of the Ministry of Transport. As will be seen from an accompanying photograph, direct lighting is cut off at a line 4 in. to 8 in. below the bottom of the windows. Special shades are fitted to lamps near the entrances to prevent escape of scattered light on to the entrance vestibules, where the door partitions are blacked off. Cylindrical shades are standard, but where the lights are near luggage racks, a special bulkhead fitting is used.

Contractors

Complete Electrical Equipment.

English Electric Co. Ltd.

Sub-contractors to English Electric Co. Ltd.

Pritchett & Gold and E.P.S. Co. Ltd. : NIFE batteries for emergency operation of control gear-brakes and doors.
Skefko Ball-Bearing Co. Ltd. : Roller bearings for motor armatures.
Simplex Conduits Ltd. : Electrical conduits.
David Brown & Sons (Huddersfield) Limited : Motor gears.

Mechanical and General Equipment.

G. D. Peters & Co. Ltd. : Door operating mechanism.
Consolidated Brake & Engineering Co. Ltd. : Compressors.
Steel, Peech & Tozer : }
Industrial Steels, Limited : }
Taylor Bros. & Co. Ltd. : } Wheels and Axles.
Blaenavon Co. Ltd. : }
John Spencer & Sons (1928) Ltd. : }
British Timken Limited : Roller bearing axleboxes.
Skefko Ball-Bearing Co. Ltd. : Roller bearing axleboxes.
Colvilles Limited : High tensile steel for underframes and bogies.
Appleby-Frodingham Steel Co. Ltd. : Mild steel.
Smith & McLean Limited : Steel for panelling exterior of body sides and roof ; deep drawing pressing steel.
Lewis Construction Co. Ltd. : Dovetail sheets for floors.
J. W. Roberts Limited : Cork sheets for floors.
Carpet Trades Limited : Carpets.
J. Holdsworth & Co. Ltd. : Trimming material for seats.
T. F. Firth & Sons Ltd. : Trimming material for seats.
Lace Web Spring Co. Ltd. : Spring fillings for seats.
Caldwell Young & Co. Ltd. : Blinds.
Walsh & McCrea Limited : Blinds.
Pilkington Bros. Ltd. : Glass.
Worcester Windshields & Casements Limited : Sliding ventilator lights.
W. A. Bonnell (1924) Limited : Veneered finishing panels.
Saro Laminated Wood Products Limited : Veneered finishing panels.
J. Latham & Co. Ltd. : Veneered finishing panels.
Northern Aluminium Co. Ltd. : Aluminium alloy fittings.
Aluminium Corporation Limited : Aluminium sheet.
British Aluminium Co. Ltd. : Aluminium sheet.
Lightalloys Limited : Alpax doors.
Joseph Kaye & Sons Limited : Locks and handles.
Westinghouse Brake & Signal Co. Ltd. : Electro-pneumatic air brake equipment.
Ferodo Limited : Composition brake blocks..
Equipment & Engineering Co. Ltd. : Destination indicators.
Bluemel Bros. Ltd. : Interior finishes (Firmoid).
Dover Limited : do. (Doverite).
Resistoid Limited : do. (Resistoid).
Metropolitan-Vickers Electrical Co. Ltd. : Welding electrodes.

Electric Railway Traction

Mobile Substations

THERE is much to be said for the provision of mobile substations on an electrified system, and the practice is wider than generally realised in this country, particularly on high-tension systems, both a.c. and d.c. It is not merely in emergency that a mobile plant is of value; it may reduce the initial cost of electrification by reducing the amount of converting equipment necessary through the elimination or partial elimination of reserve plant, not only reserves against breakdown but spare plant installed to look after extra seasonal loads. The Italian State Railways have numerous 2,000 kW mobile plants complete with transformer and rectifier for converting to 3,000 volts d.c. h.t. supply currents of anything from 11 to 66 kV; their use dates from 1931. The most modern types weigh over 70 tons and are carried on one six-wheel and one four-wheel bogies. On the 1,500-volt d.c. system of the Netherlands Railways there are several 1,000 kW mobile equipments, and the 15-kV 16⅔-cycle single-phase lines in Sweden and Germany include many mobile converting plants. A description of the Swedish design was given by Mr. Ofverholm in his article on the Swedish State electrification published in the issue of this Supplement for March 5, 1937. Hitherto no use has been made of mobile substations on the extensive 1,500-volt d.c. system in France, but shortly before the war construction of a rectifier plant was begun, and the equipment, including transformers, breakers and control panel was to be housed on two special bogie wagons. This substation was intended to augment the capacity of the Bordeaux—Hendaye line of the old Midi Railway, and was to have a nominal capacity of 1,000 kW and an overload capacity of 200 per cent. for five minutes.

Electric Traction and Speed

INVESTIGATIONS based upon the summer timetables of 1939 show that electric traction was responsible for a daily mileage of 23,970 at start-to-stop speeds of 60 m.p.h. and over. Of this total, 17,617 miles were at 62 m.p.h. or more, 7,157 miles at 66 m.p.h. or more, and 1,507 miles at 70 to 72·5 m.p.h. Although not large in comparison with the express mileage made by other forms of traction, such a mileage is quite enough to show the speed capabilities either of streamlined fixed-unit formations such as are used in the Italian high-speed runs or of locomotive-hauled trains like those on the Pennsylvania and French National systems. The five fastest runs are made by the Breda triple-car trains on the 3,000-volt d.c. system of the Italian State Railways, the runs being those between Rome and Naples and from Milan to Bologna, and the start-to-stop speeds varying from 71·2 to 72·5 m.p.h. over distances of 130 to 136 miles. After a 71·2-m.p.h. run by the Pennsylvania Railroad's Congressional between North Philadelphia and Newark, 76 miles, the Italian State Railways claim the next five fastest runs, all of them at over 70 m.p.h. Indeed, out of 14 electric runs at over 70 m.p.h. the Italian State Railways claim 10. Thanks mainly to the intensive high-speed operation over the Pennsylvania electrified tracks between New York and Washington, a daily mileage of 10,753 is worked electrically in the U.S.A. at 60 m.p.h. or more. The extraordinarily high standard of the interurban and cross-country electric services in the western half of Holland is well shown by the daily total of 4,235 miles at 60 m.p.h. and over, of which 3,084 are at 62 m.p.h. or more and 1,792 at 66 m.p.h. or more. All these services are operated by the streamlined twin-car and triple-car trains working solo or coupled in multiple-unit as required. By reason of the drastic decelerations made in 1939 to assist the French National Railways to meet their financial charges at the expense of service to the public, France could show only 3,180 miles a day hauled electrically at 60 m.p.h. or over, and of these only the 70 miles of the Sud Express run between Poitiers and Angoulême were booked at a speed in excess of 70 m.p.h. Taking the world as a whole, electric traction at speeds above the mile-a-minute rate reaches its maximum at 62 m.p.h., in which range it is responsible for a quarter of all the runs, but at 60 m.p.h. and over the proportion is only 21 per cent., and at 70 m.p.h. and over only 11½ per cent. Although the Chicago, North Shore & Milwaukee Railroad has some very fast short-distance point-to-point bookings—up to 75 m.p.h.—many of them are quite impossible with the multiple-unit stock in use at the moment, and the fastest electric run in the world in the summer of 1939 may be taken as the 72·5-m.p.h. booking between Rome and Naples (Mergellina). The fastest runs now are at 77·5 m.p.h. between Milan and Bologna, and 76·8 m.p.h. between Rome and Naples.

R. E. B. Crompton

HEAVY electric traction was one of the few fields of electrical engineering which did not at one time or another engage the serious attention of the late Colonel R. E. B. Crompton, who died recently in his 95th year. Yet his name was a household word among traction engineers, for, despite a technical knowledge which was never claimed to be in the same class as that of Ferranti or Kelvin, his personality was known in every branch of electrical engineering. This was due partly to the extraordinary length of his career, beginning with his service as a 10-year old midshipman in the Crimean war, and ending only with his death, for he was a director of Crompton, Parkinson Limited from 1927 onwards, after having severed his connection with his original company—R. E. Crompton & Company—on its reconstruction in 1912. Forty to fifty years ago he championed d.c. against a.c. for generation, and although he realised that a.c. would probably be necessary for large-scale generation and transmission, he never wholly lost faith in d.c., and within the last decade drew attention to progress made with d.c., principally as a result of the mercury arc rectifier. He made not unsuccessful experiments to mechanise the army in India nearly 70 years ago, and he was consistently ahead of most of his fellows in such fields as lighting and underground transmission, and also as regards light traction, for he was responsible in 1890 for the electrification of the Southend pier railway, which was operated by 13½-h.p. cars collecting d.c. at 200 volts from bare copper strip laid between the rails.

WORKS LOCOMOTIVES FOR ELECTRIFIED LINES

Two-power design for arduous service conditions on the L.P.T.B. lines has central gangway down long equipment compartment, and a driving position at each end

EIGHT special two-power electric locomotives have been used by the London Passenger Transport Board in the constructional and maintenance work associated with the £45,000,000 scheme of extensions and improvements now being carried out by the board, the L.N.E.R. and the G.W.R. Two of these, built by Metro-Vick and equipped with metadyne control, were described in the issue of this Supplement for February 4, 1938; the remaining six were ordered from the General Electric Co. Ltd. and embody a different form of control, and the mechanical portions were built by the Gloucester Railway Carriage & Wagon Co. Ltd. Current is supplied to the motors from big storage batteries on the locomotives or at 600 volts d.c. from a conductor rail, according to the duties and location.

The general mechanical design is the same as that of the Metro-Vick units, and apart from the axle bearings the traction motors are identical with those used in the metadyne locomotives. The nose-suspended motors are operated either at half-voltage from a 160-cell lead plate battery of 760 amp. hr. capacity, or directed at full voltage from the conductor rail, under which conditions the one-hour rating is 138 h.p. per motor.

Control Equipment

Some doubt existed as to whether a locomotive provided with a resistance starting and combination form of control could meet the widely varying conditions specified, and a motor-generator set equipment was proposed, partly in view of the fact that in America, for certain specialised work of a similar character, motor-generator type locomotives have been used. But the use of a motor-generator set results in a reduction of the work that can be obtained from the battery, since the stand-by losses and the lower running efficiency more than offset the efficiency losses in resistance starting. Therefore a system of series, series-parallel, and parallel control with carefully graded resistance steps was adopted, and is simple in operation, easy to maintain, and involves the use of equipment much lighter than that required by the alternative method.

The need for multiple-unit operation presented no difficulty as the standard G.E.C. electro-pneumatic control system using electro-pneumatic contactors was readily adaptable to this purpose. Further, it was found possible to use the standard system of driver's controls used on L.P.T.B. tube railways, the controller in the driver's cab having one handle for speed regulation, a second for regulation and a third for reversing. The shunt method of transition was adopted, as it is not only more readily adaptable for use in conjunction with the three motor-circuit arrangements (*i.e.*, series, series-parallel, and parallel) but also because the bridge method of transition has little or no advantage in the case of locomotives handling greatly varying loads.

The operation of the locomotives at 600 volts from the conductor rail and a nominal 300 volts from the batteries introduced problems in connection with the change-over from one source of supply to the other. The speed of the locomotives when taking their supply from the conductor rail approximates to that of the general traffic on the line, but under battery operation the speed is necessarily low, and although the same control equipment is suitable for both methods of operation, the resistance steps had to be carefully graded to satisfy both voltage conditions. The change-over from conductor-rail to battery operation is accomplished as follows. A master switch is mounted in each driver's cab and is of the key type, having three positions: traction, off, and battery on. This switch operates an electro-pneumatic change-over switch arranged for multiple-unit control so that if two locomotives are attached to a train, one at each end, both are under direct control from any one of the four driver's cabs.

Battery Charging

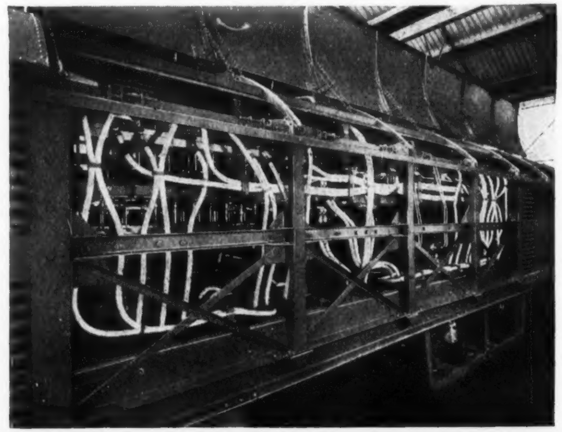
The battery is charged from the running rails, and when once put on charge by means of a suitable switch the process is almost completely automatic. The connections of the circuit are such that charging can only take place when no current for traction purposes is being drawn from the conductor rails. For charging purposes a series resistance is inserted. This, although somewhat wasteful of energy, has many advantages from the point of view of simplicity and reliability. Three rates of charging are provided by varying the series resistance. If the battery is fully discharged the full rate is automatically applied, and as soon as the battery is two-thirds charged the intermediate rate is also automatically applied by means of a voltage relay, which continues to function until the battery is fully charged. In order to keep the battery in good condition it is necessary periodically to give it a gassing charge, and for this purpose a third rate of charging is applied non-automatically. Protective equipment for the battery circuits is provided and includes an interesting arrangement whereby the charging resistance is protected, in the event of the battery being abnormally discharged, from a rate of charge that would over-heat the resistances. In this event a relay operates and introduces for a time the lower rate of charging. Since a fairly large amount of resistance is always in series with the battery, and the automatic control is based on the voltage of the battery on load, the complete charging cycle has a suitable drooping current characteristic, beginning with a high and ending with a low charging rate.

Duties

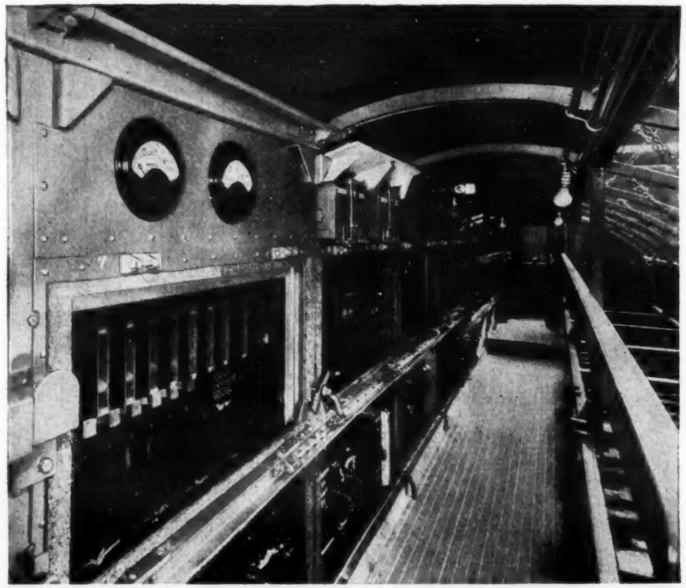
The locomotives have operated on the Central London Railway works for four nights a week with trains made up of flat wagons with a locomotive at each end, an arrangement which adds considerably to the ease of manœuvring. The total weight of a train is approximately 300 tons, and in this work the trains operate over a distance of about 14 miles, picking up and unloading material such as rails, sleepers and ballast at different places *en route*. Other work includes trains for rail laying, concrete mixing, cable laying, ballast spreading, and yard shunting.

It was specified that two locomotives, one at each end of a train, should be capable of hauling trailing loads of 200 tons up gradients of 1 in 61 with occasional gradients of 1 in 40, and that they should be able to inch forward a train up a gradient of 1 in 30 on a rough constructional track, in which irregularities might involve one sleeper being half-an-inch above or below the next. Each locomotive also had to be capable of hauling 100-ton trains for cable-laying purposes at steady speeds, without jerks, of between 2 and 3 m.p.h. All these requirements were to be met by the locomotives using either the batteries or the conductor rail without the batteries. The batteries themselves had to be capable of being re-charged in 12 hr.

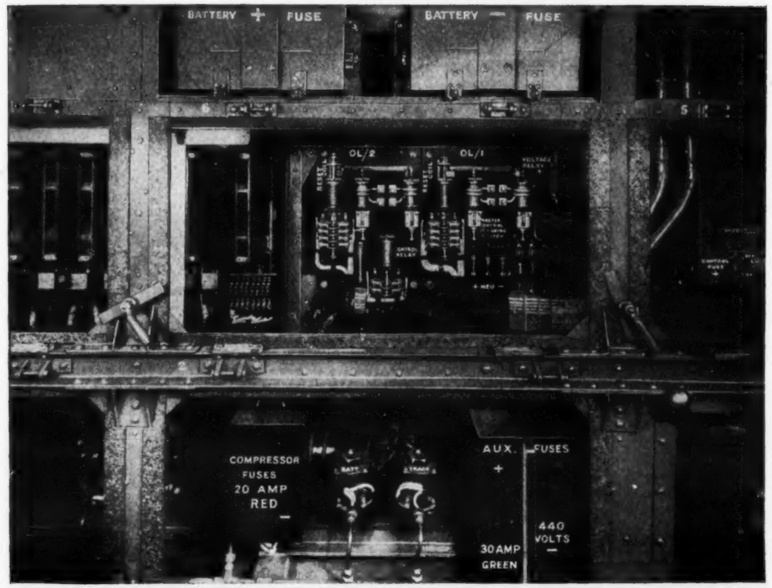
The six two-power locomotives ; each is fitted with four 138 h.p. motors



A view of the rear of the apparatus cubicle



Interior view of the central equipment compartment



Relays for overload protection, battery and auxiliary fuses

VIEWS OF THE L.P.T.B. TWO-POWER G.E.C. LOCOMOTIVES WHICH WORK FROM THE CONDUCTOR RAIL OR FROM A BATTERY

DUTCH ELECTRIFICATION PLANS

About 70 miles of route are now being converted to 1,500-volt d.c. traction and a large amount of stock is being built or rebuilt

ELECTRIFICATION on the Netherlands Railways is being pushed steadily forward. Scarcely was the work on the middle portion of the system finished than conversion of the Arnhem—Nijmegen and Harmelen—Breukelen lines was begun. This work is not yet complete but nevertheless it has been decided to electrify the Amsterdam—Amersfoort (44 km.), Hilversum—Utrecht (17 km.) and Blauwkapel (Utrecht)—Amersfoort (16·5 km.) routes. Although the total length of these lines is only 77·5 km. (48·2 miles), they carry a considerable traffic. The whole summer service of 1939 comprised 10,500,000 steam train-km., 5,800,000 electric train-km., and 1,800,000 diesel train-km. With the electrification now sanctioned the electric train-mileage will be increased by 1,300,000 km. On the present electrified routes, amounting to 500 km. (311 miles), 5,800,000 train-km. were run, or 11,600 train-km. per km.; on the lines to be electrified the corresponding figure will be 16,800 train-km., a value much above the average for the entire electrified system. Electric train mileage now totals more than half that run by steam, and the new work will make the ratio about three-quarters.

New Rolling Stock

The work just sanctioned will not be completed until 1941, and will include a good deal of alteration to station arrangements and other works. The present non-streamlined electric stock is to be modified to make it more generally available, the top speed being increased to 125 km.p.h. ($77\frac{3}{4}$ m.p.h.); the motors are to be improved and the nominal voltage will be 1,500 instead of 1,400. Some attempt at streamlining will be made, especially on the current collectors. There are to be 15 new two-car trains and 25 new five-car trains. The latter will consist of three close-coupled third class vehicles, one third class and kitchen car, and a first and second class car, the seats being either side of a central gangway. Some seats are to be arranged to face in one direction only instead of to face each other. The two-car trains are to have one third class section and one serving for second and third. Luggage accommodation is to be particularly large and these sets are to be used partly to strengthen trains normally carrying heavy traffic. Compared with existing stock the sides will slope rather more than previously, and the signs for entrance and exit be clearer than at present. The present three-car streamlined electric trains are to be increased by an extra car, and 29 of the existing 53 two-car trains are to be made into three-car sets. Altogether 221 new electric cars are to be built, and will contain 2,120 second class seats and 11,788 third class seats.

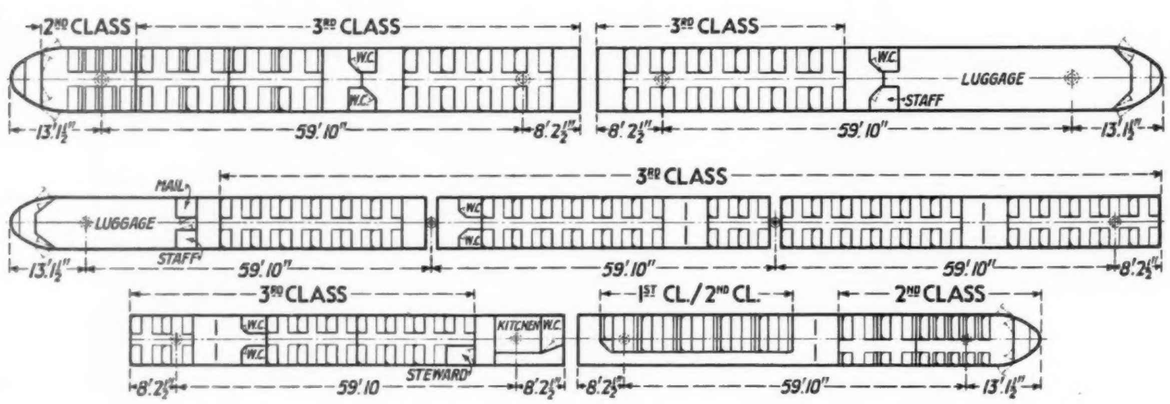
The new three-car trains are to have 24 second and 128 third class seats; and the new four-car sets rebuilt from the triple-car units, 48 second and 224 third seats. Investigations have indicated that the proportions of first and second to third class seats should be as 1 is to 1·67; but to give the former classes more comfort a ratio of 1 to 1·5 has been adopted. The original intention to alter the number of seats in a row from 5 to 4 in the old trains is not to be carried out, as it would reduce the accommodation too much in view of the expected traffic.

The cost of the newly-sanctioned electrification is estimated at 28,000,000 fl., inclusive of the rise in prices occasioned by the war, considered to be equal to 7,000,000 fl. Of this sum about 15,000,000 fl. is for the rolling stock.

Electrification is expected to increase the traffic 15 per cent. and reduce the working expenses to an extent which will be represented by an increase of 1,000,000 fl. in the net revenue. The advantages to the public will also be appreciable: better services, faster runs, and generally greater convenience.

Current Consumption

Mr. W. Hupkes, Joint General Manager, recently spoke of past and future electrification schemes. The Netherlands Railways desired to extend electrification in view of the good results which had been obtained. The price of current formed a large part of the traction costs—60 per cent. at 3 cents per kWh and 45 per cent. at $1\frac{1}{2}$ cents per kWh—and was a deciding factor in the case. For some years it was the price of power which prevented electrification going ahead. The saving (said to be 30 per cent.) gained by streamlining the electric rolling stock in conjunction with a fall in the price of energy opened up new



Floor plans of the twin-car and five-car trains now being built in Holland

prospects for electric working. The government, which had refused the railways permission to produce their own power, had no control over the price. Power suppliers in the west of the country, mostly city or municipal authorities, had asked a high figure; but in the electrification of the central area of the Netherlands Railways, power came from provincial undertakings which supplied energy at lower prices and did not make very high profits. Their figure was 1 cent per kWh lower than that of the city power stations in the west, and this produced an appreciable difference when 100,000,000 kWh a year were consumed, amounting to about 1,000,000 fl. If further work was to go on power must be had at a reasonable figure.

Possible Future Conversions

The conversion of the Dordrecht—Roosendaal (Esschen) line was under review, whether or not the electrification of the line from Roosendaal to Antwerp was undertaken. Such a conversion would give a convenient connection between the provinces of Holland and Zeeland with only one change. Conversion of the Eindhoven—Maastricht line was also a possibility, and if accomplished would bring the outermost parts of the country into better communication with the central portion. Another project for the future was the Amersfoort to Twente and Groningen lines. By 1941 there would be about 596 route km. (370 miles) electrified, comprising about 2,400 track km. (1,491 miles). The purchase of some electric locomotives would be included in the 1941 estimates; they would haul the international trains at a speed approaching that of the streamlined multiple-unit electric trains, and would eliminate one of the minor difficulties associated with the operation of the present Dutch electrified system.

Map showing the Dutch electrified system and the conversion work in hand or about to begin

Electrification of the Swiss South-Eastern Railway

Motor-coach working of 15-kV single-phase system adopted for heavily-graded adhesion line connecting the Lucerne and Zurich lake basins

ONE of the last Swiss private railways of importance to be steam-worked was the Südostbahn (South-Eastern Railway), on which electric traction commenced on May 15, 1939. This is a standard-gauge system 49 km. (30½ miles) in length, consisting of a line from Arth-Goldau, on the Gotthard route, to Pfäffikon on the lake of Zurich and across the latter on a dam to Rapperswil; a branch from Biberbrücke to Einsiedeln; and a line connecting Wädenswil, on the Zurich—Sargans main line, with the Pfäffikon—Goldau route at Samstagern. The original line was that from Wädenswil to Einsiedeln, opened on May 1, 1877, and the Südost services still consist of trains from Wädenswil to Einsiedeln and from Rapperswil to Arth-Goldau, using the same track between Samstagern and Biberbrücke. The present company was constituted in 1889, taking over the Wädenswil-Einsiedeln Railway; the Pfäffikon—Einsiedeln and Biberbrücke to Arth-Goldau sections were opened on August 8, 1891. The short line across the lake of Zurich had been opened in 1877 by a separate company.

The system is entirely single-track, with long inclines at 4·6 to 5 per cent. (1 in 22-20) from Arth-Goldau, Wädenswil and Pfäffikon up to the high plateau separating the lake of Zurich from those of Lucerne and Zug. There are only four short tunnels, but there are several high bridges at the Goldau end of the line. Only 8·6 km. (5·35 miles) of the system are level, and 19 km. (11·8 miles) have a gradient of 4 per cent. (1 in 25) or more. Of a total of 13 steam locomotives, 11 were built in 1891 or earlier, and the greater part of the passenger rolling stock, entirely 4-wheel, was antiquated and very uncomfortable. Modernisation of equipment could no longer be delayed and electrification, first contemplated in 1920, was decided on in 1935, after the alternatives of diesel traction and road services had each received careful consideration. A thorough financial reorganisation of the company, on which loans and subsidies from the Government and the cantons concerned were conditional, was completed early in 1938 and conversion was then taken in hand.

Current Supply

The terminal points and Pfäffikon being stations on the electrified Federal lines, the standard 15-kV single-phase overhead system was adopted as the only possible one, and current is obtained from the Etzel power station of the Federal Railways and Nordöstschweizerische Kraftwerke at a point near Pfäffikon station. A second feeding point has been provided at Steinerberg, near Arth-Goldau, at which current can be provided from the Federal Railways substation nearby at Steinen in case of emergency or abnormally heavy traffic. The measuring instruments at Pfäffikon are so arranged that current regenerated by descending trains will automatically reduce the supply of current from the Etzel works.

The overhead catenary line was built by Furrer & Frey, of Zurich and Berne, with the method of slanting suspension on curves. An isolating section is provided just north of Biberbrücke station, enabling the contact lines to be

divided into two independent divisions when both the Pfäffikon and Steinerberg feeding-points are brought into use. Under normal conditions, or if in an emergency the whole system is fed from Steinerberg, this isolating section is under tension. A similar section separates the S.O.B. contact line from those of the Federal Railways at Arth-Goldau.

Lineside telegraph and telephone lines have been replaced by cables, and the opportunity was taken to instal selector telephone equipment at all stations. Track improvements to permit of higher speeds and heavier rolling stock, and strengthening of bridges, involved a total expenditure of some **400,000** fr. In addition, the railway contributed to the extent of **480,000** fr. to the cost of strengthening the dam between Rapperswil and Pfäffikon. This dam is the property of the S.O.B., but also carries an important road, and the railway company had up to the time of electrification been compelled to maintain and repair it, although a large proportion of the heavy motor traffic using the road is in direct competition with its own services. The road will in future be maintained by the public authorities concerned. The work of strengthening the dam and the bridge at the Rapperswil end could not be completed at the same time as electrification, and in order to avoid working this short section by steam traction the track was shifted to a temporary trestle, on which trains pass at low speed, with provisional overhead equipment. The main sheds and depot at Samstagern have been enlarged and provided with the necessary equipment for repairs to and maintenance of electric rolling-stock. At Biberbrücke, the depot for permanent-way materials was enlarged to accommodate spare electric line equipment.

New Motor-Coaches

The electrical equipment of the eight new motor-coaches was supplied by Oerlikon as general contractor and Brown Boveri and Sécheron as sub-contractors; the bogies and compressors were supplied by the Swiss Locomotive & Machine Works, and the bodies by the Swiss Industrial Company, Neuhausen, and the Swiss Wagon & Lift Works, Schlieren.

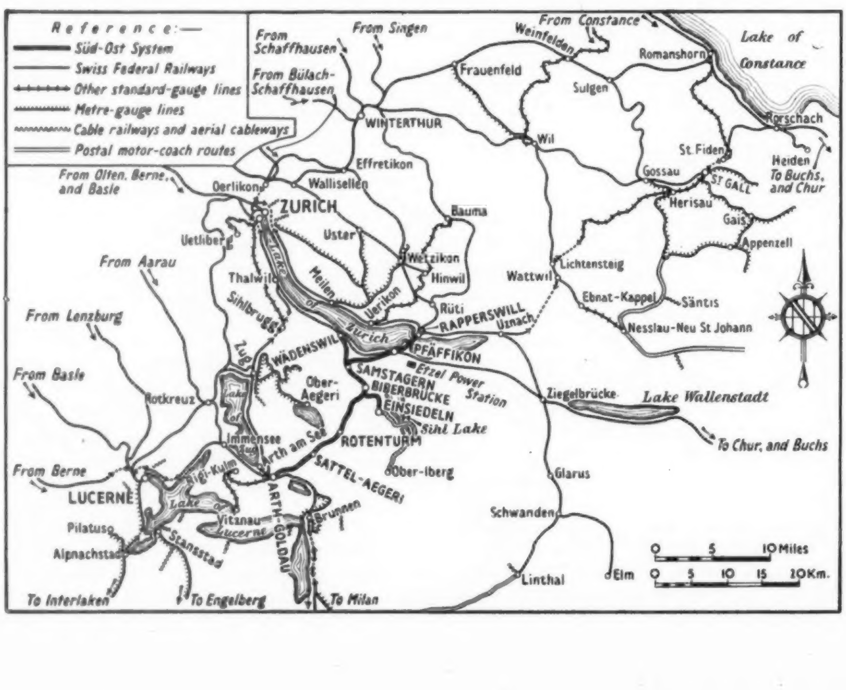
The cars are 19·6 m. (64 ft. 3 in.) in length and weigh 43·5 *tonnes*, of which 15·5 *tonnes* represent the electric equipment. They are capable of hauling a load of 50 *tonnes*, but their interior arrangement makes it possible to provide passenger, luggage and mail services without attaching trailers. Two large third class compartments are reached through a roomy vestibule at each end, which is entered by sliding doors on both sides and constitutes the driving compartments and is also used for baggage and mail as necessary. Seats total **64**, in addition to which **14** passengers can be accommodated on folding seats in the end compartments and **40** standing. The driver is seated with the controls and usual instruments grouped on a sloping desk in front of him. A mirror on the left hand of the compartment enables him to see that side of the car and appropriately control the closing of the doors.

The body is supported on four-wheel bogies, each with two motors coupled in series. The transformer and most of the other equipment is fitted under the floor of the coach. A lightweight pantograph is mounted at one end of the vehicle. The one-hour output at **54** km.p.h. (**33·5** m.p.h.) is **960** h.p. with a tractive effort of **4,800** kg., and the continuous output is **840** h.p. at **57** km.p.h. (**35·4** m.p.h.) with **3,960** kg. tractive effort; the maximum speed is **80** km.p.h. (**50** m.p.h.).

Services

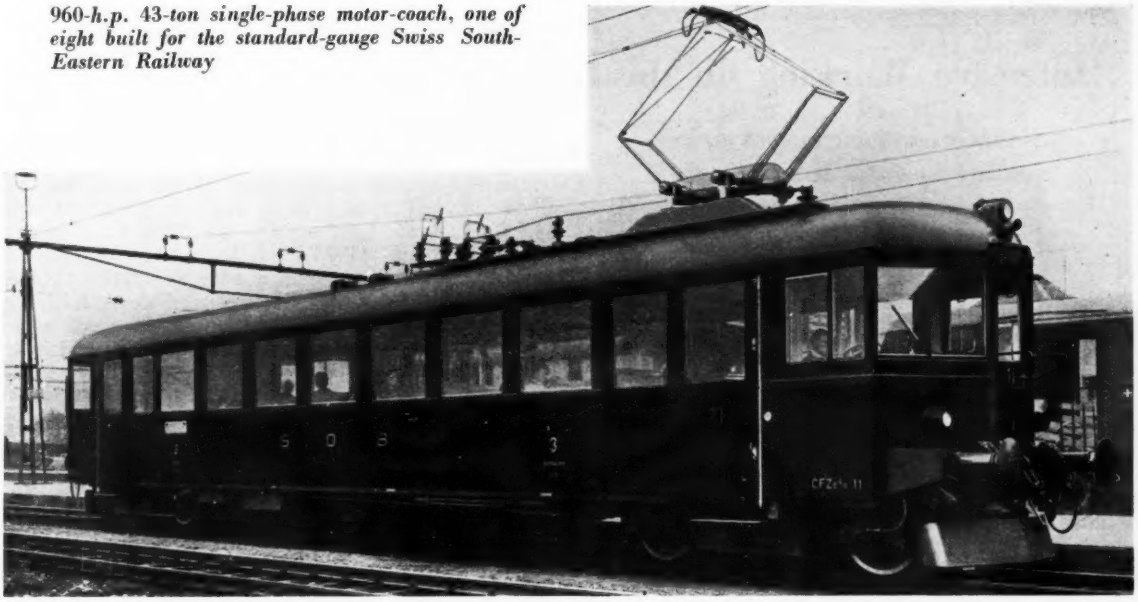
The original intention was to work the line with both motor-coaches and locomotives, but as goods traffic is light and peak passenger traffic only occasional, eight motor-coaches were considered sufficient, supplemented by engines or motor-coaches hired from the Federal Railways when required for pilgrim or winter sports traffic. Unfortunately, delivery of the new rolling stock could not be made until some months after the date appointed for inauguration of electric traction, and arrangements were therefore made with the Swiss Federal Railways and the Bodensee-Toggenburg Railway for the loan of two motor-vans and two locomotives respectively, which accordingly worked all traffic until the end of **1939**.

Since conversion there has been a **50** per cent. increase in services, and the best times have been reduced from **41** to **30** min. between Wädenswil and Einsiedeln, and from **82** to **56** min. between Rapperswil and Arth-Goldau, with similar accelerations in the opposite directions. As a consequence, greatly improved connections are afforded with the Federal lines at junction points. Before the war there were three daily through services (since reduced to two) from Arth-Goldau *via* Rapperswil to St. Gall and



Map showing the recently converted South-Eastern Railway in Switzerland and its relation to and connection with the Swiss Federal, Bodensee-Toggenburg and other railways

960-h.p. 43-ton single-phase motor-coach, one of eight built for the standard-gauge Swiss South-Eastern Railway



Romanshorn over the Südost, Federal (Ricken line) and Bodensee—Toggenburg systems. An overall time of 129 min. from Arth-Goldau to St. Gall, a distance of 97·5 km. (60·5 miles) over a very difficult route, entirely single-track, is quite a good performance, particularly as it includes 10 station stops, of which that at Rapperswil occupies 9 min.

The total cost of conversion was 5·2 million fr., of which 1·2 million fr. were covered by subsidies on account of unemployment relief, and the balance by loans from the Swiss Government and the cantons of Zurich, Schwyz, and St. Gall in accordance with the terms of the law of October 2, 1919, regarding future electrification of private railways.

Norwegian Electrification

THE report of a committee set up by the Norwegian Storting to consider railway electrification recommends that the Nordagutu—Neslandsvatn (Sörland railway); Lilleström—Swedish frontier (Kongsvinger railway); Neslandsvatn—Kristiansand (Sörland railway); and Lilleström—Hamar (Dovre railway) lines should be electrified in that order. This is a majority report; a minority report signed by three of the committee recommends that the Lilleström—Hamar conversion proposal be given preference over all other electrification schemes, as the Dovre railway is the main traffic artery, and carries more traffic than any other Norwegian main line. There is a tacit understanding that the Kristiansand—Stavanger section of the Sörland railway will be electrified from its opening, owing to the many and long tunnels—up to six miles in length—totalling 21 miles; construction is not yet complete.

Conversion in Progress

Electrification on the State Railways is making steady progress. On the Östfold line the Oslo—Kornsjö *via* Halden section is being converted, and electric trains began to run between Halden and Kornsjö, 32 km. (20 miles) on September 15, 1939; between Kolbotn and Ås, 18 km. (11 miles) on October 1; and from Ås on to Moss in January of this year. It is hoped to have the section between Moss and Frederikstad opened in May of this year. The remaining section from Frederikstad to Halden 43 km. (26¾ miles), was not scheduled for completion until May, 1941, but the work is being accelerated and may be finished next autumn. The total length of the Östfold line is 169 km. (105 miles). At the moment traffic on the Halden—Kornsjö section is being operated by the electric locomotives of the Swedish Dalsland Railway, the southward continuation of the Norwegian Östfold line. The eight new 2,800 h.p. electric locomotives intended for operation on the Östfold railway will not be delivered until July, 1940, and the motor-coaches built during the last few years are working only the suburban section out to Ski. Therefore three of the Drammen railway double-bogie locomotives have been transferred to haul goods trains.

Further, two of the 3,600 h.p. twin-unit electric locomotives of the Ofoten railway have been brought from Narvik through Sweden to Oslo where the normal 3,600 h.p. formations have been separated and now operate as two 1,800 h.p. sets. This transfer is practicable because of the great decrease in the Swedish iron-ore exports *via* Narvik since September last. These 1,800 h.p. half locomotives can be driven from only one end, and as the railways from Oslo East station are ascending they are used to push the trains out of the terminus assisting the locomotive in front, and for hauling trains inwards to Oslo.

VOLK'S ELECTRIC RAILWAY.—The Brighton Corporation Transport Committee reported to the Council on February 22 that an offer had been received from Magnus Volk Limited for the continued management by the company of Volk's Electric Railway after March 31 next, on a basis of 22½ per cent. of gross receipts plus £500 p.a. towards the rates, but without, under wartime conditions, the guaranteed minimum payment of £2,000. The Committee recommended, however, that the agreement with Magnus Volk Limited should not be extended after March 31, but that the Brighton Corporation Transport Manager should prepare proposals for the operation of the railway by the Corporation.

Intensive Working on the Brussels—Antwerp Electric Line

Six trains an hour in each direction are operated throughout the day by multiple-unit formations over 27½-mile double-track route

PRIOR to the transfer of the semi-fast and local traffic to the electric line, the Brussels—Antwerp steam line was served in both directions by **86** light trains and railcars (including the railcar runs on the Brussels—Vilvorde section); **38** heavy local trains; **9** fast and semi-direct trains; and **20** international trains. The electrified line was opened in April, **1935**.

Since October **8, 1939**, all this traffic has been transferred to the electric line, except the international trains and three locals in each direction. The latter run between Brussels and Malines only and are used by workmen having their occupation in the northern industrial suburbs of Brussels—Schaerbeek, Haren, and Vilvorde in particular. These three local trains were retained in order to avoid acquiring too great a number of new electric sets, some of which would have been needed only for one hour in the morning and one hour in the evening.

The new electric service was to be worked daily by means of about **38** fast trains, **30** semi-fast trains, and **38** local trains, which were to be distributed as follows:

From **7.20** *a.m. to* **8.30** *p.m.*

The train service was to be rhythmical and all stations on the line were to be served at regular time intervals by the same kinds of train (standardised timings):

(*a*) Fast trains, making the run in **31** min., and starting at the exact hour and the half-hour from Brussels (Nord) and Antwerp (Central) stations.

(*b*) Semi-fast trains performing the journey in **41** min., starting at **15** and **45** min. past the hour.

(*c*) Local trains taking **46** min. to cover the distance, and starting at **4** and **34** min. past the hour.

From **8.30** *p.m. to* **7** *a.m.*

Standardised timings are not observed, and the timetables are drawn up to suit the observed requirements of passengers.

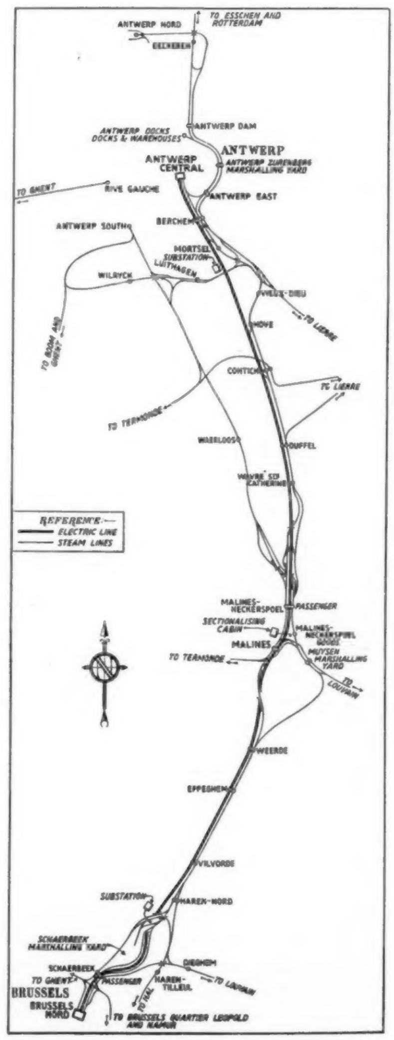
Owing to the present international situation and the consequent decline in traffic, the schedules under both headings were not put into force as projected and some trains were cancelled during slack hours.

Signalling Sections

The appended graphs represent the typical timings applying to heavy traffic periods. They show the alterations carried out to the signalling arrangements to allow the projected timings to be observed. Only the block signals are shown on the diagrams. The object of these alterations was to allow trains to start at 3-min. intervals instead of 4 min., as was formerly the case, in order to give the working sufficient elasticity. They had also to make it possible for any train to keep to its schedule when the preceding train ran one minute late.

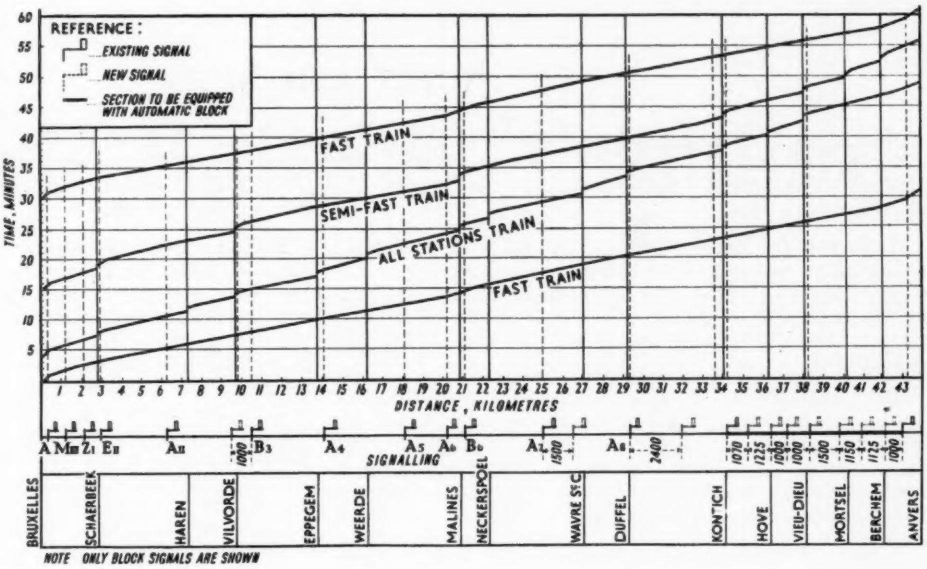
In the Brussels—Antwerp direction, a local block section had to be inserted between Haren and Vilvorde, a second between Malines and Wavre-Ste. Catherine, and a third between Duffel and Kontich. On the Kontich—Antwerp section, where the schedules of the three successive trains—local, semi-fast, and fast—get particularly close to each other, the automatic block was deemed an indispensable feature. The lengths of the block sections have been computed so as to provide the greatest possible working facilities, account being taken at the same time of the best visibility conditions of the line when choosing the location of the signals. On the Kontich—Antwerp section, 9·575 km. (5·95 miles) long, eight automatic block sections have been provided, and this solution avoided the installation of a number of intermediate signal boxes, or of a number of successive block signals which could not possibly be worked by the existing boxes owing to the heavy traffic.

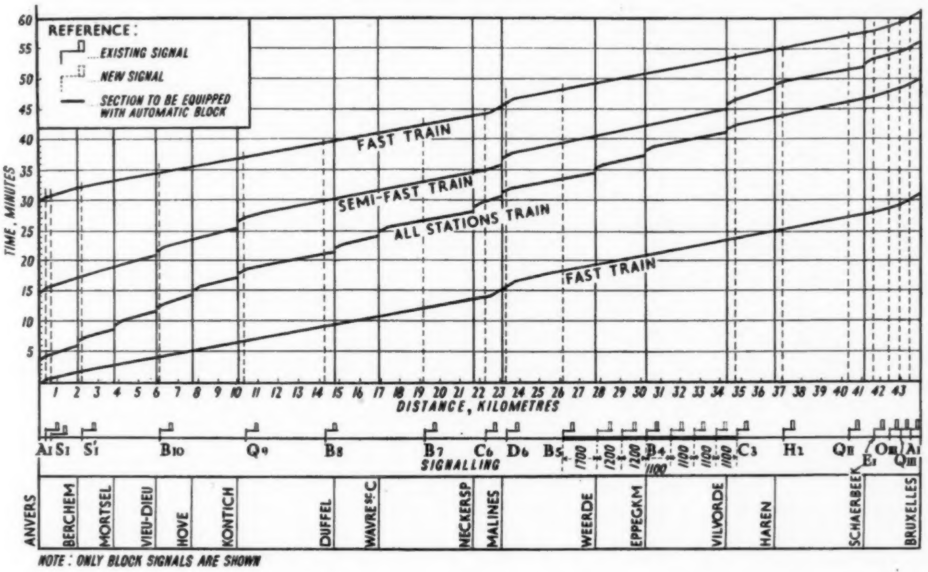
In the Antwerp—Brussels direction no new local blocks had to be inserted, but on the Malines—Brussels section the schedules of the local and semi-fast trains are close to each other as far as Vilvorde, then widen again, as the local trains do not stop between Vilvorde and Brussels. The investigation into the signalling arrangements showed that, as on the Kontich—Antwerp section in the Brussels—Antwerp direction, it was necessary to equip the Weerde—Vilvorde section with automatic block signalling. This



Map of the Brussels-Antwerp routes of the Belgian National Railways showing the steam and electrified tracks, and the connecting lines. Electrification is on the 3,000-volt d.c. system

Graphic timetable and signalling diagram of the down track on the Brussels-Antwerp electrified system of the Belgian National Railways. Automatic block signalling is now in operation between Kontich and Antwerp





Graphic timetable and signalling diagram of the up track on the Brussels-Antwerp electric line. Automatic block signalling is in force between Weerde and Vilvorde

section of the line is 8·5 km. (5·3 miles) long and includes seven automatic block sections.

The automatic block system adopted is based on the " normally clear section " system. In opposition to the principle generally accepted on foreign railways, where the block is always permissive, the absolute block system remains in force on the whole of the Brussels—Antwerp electric line, even on the parts equipped with the automatic block. In case of failure of an automatic block signal, the train guard has to report by telephone to the signal box located forward, following the section equipped with the automatic block, in order to obtain leave to pass this signal at danger. This solution, which may appear illogical at first sight, owing to the delays it may cause to the traffic, has been adopted for reasons of uniformity. It has been accepted owing to the short section length.

The automatic signals have the same appearance as the ordinary daylight signals installed on the line, and the aspect code is identical. The block signals have an independent distant signal light when the length of the block exceeds 1,500 m. (1,640 yd.). In order to distinguish the automatic from the hand block signals, the former have been provided with a panel illuminated at night and bearing the letters AUT. The sole object of this panel is to remind drivers running on the wrong line that they are not to comply with the automatic block signals.* Owing to their automatic operation, the latter signals cannot show the line clear aspect when the section they protect is occupied by a train in difficulties, or by a service train.

Another particular feature is that the optical approach indicators of the distant automatic signals have cat's eye reflectors to increase the visibility. Their object is to prevent as far as possible drivers from passing a stop signal that has gone out. As the block system is of the normally clear section type, it was feared that, if special precautions were not taken for spotting the location of the signals, owing to the short length of the blocks a driver already sighting the following signal at " line clear " might inadvertently pass the signal that had gone out.

* As is known, the signalling of the Brussels—Antwerp line is so combined that trains running on the wrong line must comply with the fixed signals of the track which is out of service. This arrangement has made it possible to run at the normal speed of 120 km.p.h. (75 m.p.h.) on the wrong line.

NOTES AND NEWS

New American Locomotives.—The General Electric Company (of America) has received an order from the Nevada Consolidated Copper Company for seven d.c. electric locomotives.

J. E. van den Burg.—Mr. J. E. van den Burg, electric rolling stock assistant for maintenance and repairs to the Chief of Motive Power of the Netherlands Railways, retired at the beginning of February, after 39 years of railway service, of which 30 years were spent in the electric traction department.

H.T. Cable.—A specimen of Callender's impregnated pressure cable which 18 months ago was subjected to extensive tests, amounting to 5,000 hr., at 260 kV in Holland, has recently been given a test of 2,300 hr. and 104 heat cycles at a tension of 350 kV, and showed no deterioration of the cable dielectric.

Greek Motor-Coaches.—A number of double-bogie motor-coaches with pantograph collection of low-tension d.c. have been built by the Cia. Generale di Elettricita, of Milan, for stopping service on the line between Piræus and Perama, in Greece, a distance of five miles. Frequently two vehicles are operated in multiple unit.

German Suburban Stock.—The first of the new motor-coaches and trailers for the modernised electric suburban lines in Hamburg have been placed in service on the Ohlsdorf—Poppenbüttel section. They are of all-metal construction with smooth rounded ends, and are equipped with the Scharfenberg multi-purpose automatic coupler.

Sir David Salomon's Scholarship.—This award has been made by the Institution of Electrical Engineers to Mr. Thomas Earnshaw Calverley on the basis of the work he has done at King's College, London University; the value is £100. Mr. Calverley is the son of Mr. J. E. Calverley, chief engineer and manager of the English Electric Company's traction department.

Australian Electrification.—During 1939 the New South Wales Government Railways opened to electric traction the Regents Park—Bankstown and Kingsgrove—East Hills sections of the Sydney outer suburban area, bringing the electrified route mileage up to 104. During the fiscal year 1938-39 orders were placed for 24 steel motor-coaches and 24 trailers, and alterations were made to part of the existing stock to increase the total carrying capacity by slightly decreasing the number of seats and appreciably increasing the standing room. The electric train-mileage was 7,254,872 and the current consumption, including lighting and heating, 203,714,725 kWh.

Copenhagen Electrification.—Once again the electrification of the Valby-Ballerup section of the Copenhagen-Frederikssund line is being slowed up, so that it is now not expected to be completed before the autumn of 1941. This electrification scheme was originally scheduled for completion a couple of years ago, but the plans have been altered several times, hence the delay. It was originally intended to retain the present line with its numerous level-crossings; but the plan now being carried out comprises the abolition of most of these and the building of an entirely new alignment on an embankment alongside the old line for part of the way. The present slowing-up is caused by the desire for fuel economy, but the expected great increase in traffic density on the introduction of electric working would not materialise at the present time. Since the fiscal year 1932-33, the receipts from the suburban passenger traffic round Copenhagen have increased by 3·7 million kr., most of which is due to the electrification, first opened in 1933.

Italian Electrification.—During the year ending June 30, 1939, the Italian State Railways put into traffic 137 new electric locomotives, 47 solo motor-coaches, 4 triple-car streamlined electric trains, and 20 multiple-unit train sets. The electrified route mileage on the State system is stated to be now 5,131 route km. (3,188 miles). From October 28, accelerations have been made in the *rapido* services worked by the triple-car streamlined trains between Milan and Naples; the fastest runs between Rome and Naples now average 123 km.p.h. (76·8 m.p.h.) and 125 km.p.h. (77·5 m.p.h.) between Rome and Bologna. The fastest trip from Milan to Naples, 841·5 km. (522·7 miles), now takes 7 hr. 26 min. inclusive of 11 min. standing at Bologna, Florence and Rome. The Gallarate (Milan)—Domodossola line is the next route scheduled for electrification on the 3,000-volt d.c. system, and the change-over is to take place on October 28, 1940.

A.C.-D.C. Interchange.—The extension of the Italian State Railways' electrification to Chiasso, on the Swiss frontier, has provided another example of two different electrification systems meeting, the Italian State 3,000-volt d.c. system joining the Swiss Federal 15,000-volt single-phase equipment; both have overhead current collection. Certain tracks in the station, where traffic arrangements make it suitable, are kept exclusively to the trains of one or other administration, but special arrangements have been made for through traffic, with a neutral isolation gap between the two contact wire systems. Locomotives run in with lowered pantographs and are shunted by steam locomotives back to their own area. The steam locomotives are also used to shunt rolling stock where the use of an electric locomotive is either impossible or inconvenient. Similar interchange stations are found at Brennero and (d.c./three-phase) at Viareggio, but at Chiasso it is understood that over two tracks the contact line can be fed either with 15-kV single-phase or 3,000-volt d.c., the feeding arrangements being interlocked with appropriate colour-light signalling to ensure correct use.

Swiss Lightweight Stock.—A new departure for the Rhaetian Railway was the recent introduction of lightweight rolling-stock with a view to improving services without unduly increasing the working expenditure. Since electrification of its lines in 1913-22, the Rhaetian Railway has used locomotives, mainly of C-C type, for all traffic, contrary to the usual Swiss metre-gauge practice of motor-coach haulage for passenger trains. Orders for the new lightweight stock were placed in 1938, and delivery was due in September and October last year, but was delayed on account of the war. Of a total of four motor-coaches and eight trailers, two motor-coaches and three trailers have now been delivered and were placed in service on December 20 last, after the usual trials. The remaining vehicles are expected to be delivered in the course of the winter. The 55-*tonne* motor-coaches have a maximum speed of 65 km.p.h. (40 m.p.h.) and a one-hour rating of 620 h.p. They seat 48 passengers and can haul two lightweight trailers, each seating 68, over the steepest grades. The tare weight of the train is 65 *tonnes*, as against 106 *tonnes* for an electric locomotive-hauled train of similar capacity

Electric Railway Traction

Southern Railway Electrification

WE have become accustomed to wait for the annual general meeting of the Southern Railway with an interest greater than that which we normally devote to matters mainly concerned with pounds, shillings, and pence, because for several years past Mr. R. Holland-Martin, the Chairman of the company, has made a point of giving particulars of the statistics and traffic of the extensive electrified area. In his speech this year, Mr. Holland-Martin remarked that in the five years allocated to certain electrification schemes—culminating in the conversion of the Chatham and Maidstone lines, opened to electric traction on July 2, 1939—267 route (619 track) miles had been electrified and 828 electric vehicles built at a cost of £8,500,000. Southern electric lines now totalled 709 route miles, equivalent to 1,760 track miles. On January 1, 1939, the Reading, Ascot, and Aldershot—Guildford lines had been turned over to electric traction with an increase of 58 per cent. in the train mileage. The electrification of the Chatham and Maidstone lines had resulted in a 42·7 per cent. increase in the train mileage over those sections; during the first two months' electric working there was an increase of 54,000 in the number of passengers carried and of £4,000 in the receipts. Over the whole electrified area the number of passengers carried was 195,000,000, and the receipts were £6,100,000—an increase of 2·3 per cent. over the preceding year. Mr. George Ellson, in his recent presidential address to the Engineering Society of the City & Guilds College, said that the Southern Railway had spent £6,700,000 on civil engineering works connected with electrification, including the laying of hundreds of miles of conductor rails and high-tension and low-tension cables, and the remodelling and improvement of a large number of stations.

Clean Air for Motors

CONSIDERABLE emphasis was given in the discussion on Mr. H. H. Andrews' paper before the Institution of Locomotive Engineers (see page 35 of this Supplement) to the necessity of clean air being blown through the traction motors of multiple-unit trains. In the normal type of installation comprising self-ventilated nose-suspended motors with small rail clearance, the fan on the armature shaft picks up a good deal of track dust, and the current of air and dust created by the motion of the train is such that even if the motor ventilating air is taken in at the level of the coach waist rail a large amount of foreign matter is entrained. An appreciable proportion of the maintenance troubles of traction motors being due to inadequately filtered cooling air, ventilating ducts leading from the bogie to the car roof have been considered desirable in several instances, *e.g.*, the Liverpool—Southport trains described in our March 5 issue. A similar arrangement has been provided in the Lyntog diesel-electric sets of the Danish State Railways, the reason in this case being the quantity of fine snow drawn into the motors during the winter season; in Denmark the problem has been considered of sufficient importance to warrant a slight diminution of seating accommodation under certain conditions. Drawing air into the motors from the inside of the car does not appear to give uniformly successful results. The problem is considerably accentuated in urban and underground railways over which operate fast and frequent services, because of brake shoe dust. For example, the London Passenger Transport Board has been using well over 200,000 tons of cast-iron brake blocks in a year, of which perhaps two-thirds finds its way on to the track or into the motors; special attention is therefore given to the ventilating arrangements. Some engineers feel that as the efficiency of the fan on the armature shaft is small, it is better to fit separate motor-blower groups of small capacity, which give adequate cooling and use clean air drawn in through the roof, but forced-ventilation is still very unusual for multiple-unit trains. In the Italian high-speed sets air comes from the inside of the coaches, but as the saloons are air-conditioned the motor ventilating air is less contaminated with dust than in normal installations. Efficient motor ventilating arrangements on multiple-unit stock are very difficult to obtain if small radius curves are numerous, because of the play required by the bellows connection.

Frequency Changing

THE generation of three-phase energy in the U.S.A. appears to be carried out at a standard frequency of 60 cycles, and the changing of this into current at a periodicity of 25 cycles, as used on the Pennsylvania Railroad and other extensive single-phase electrifications in the States, formed the basis of a paper on network coupling read by Mr. O. K. Marti before the American Institute of Electrical Engineers in January. The advantages of an electronic rectifier-inverter frequency-changer compared to rotating equipment were stressed in the paper, particularly the instantaneous starting up, the lack of special starting equipment, and the small weight and cost of the control apparatus. However, such converters cause distortion in the three-phase supply network unless large and costly energy-storing devices are used, whereas with rotating equipment momentary energy differences between the three-phase 60-cycle input and the 25-cycle output are taken care of by the inertia of the rotors. There is some difference of opinion as to whether static frequency-changing equipment occupies less space than equivalent rotating machinery; indeed, American opinion is by no means decided that static apparatus is developed far enough for it to replace rotary converters, although one view is that it could be perfected with half the effort required to develop fully the Scherbius-controlled rotary converter. Rotary traction frequency-converters may operate with an efficiency of 95 per cent. at 60 per cent. of full load. Another suggestion which has been made is that a satisfactory form of static frequency-changer might permit of feeding into traction power systems at numerous points, thereby doing away with transmission lines.

THE PENNSYLVANIA RAILROAD ELECTRIFICATION

An account of the greatest American electrified system and its power supply and distribution networks

JUST 40 years ago the Pennsylvania Railroad acquired control of the Long Island Railroad, and the separate plans for New York termini on which these systems had been working were merged into a scheme for a joint terminal. Electrification was sanctioned as the motive power to be used, and when the Pennsylvania's tunnels were bored under the river to connect the Jersey City side with Manhattan, the section was made big enough to take either overhead catenary lines or third rail, the beginning of a wisdom which has characterised almost all the Pennsylvania's conversion work to this day.

Low-Voltage D.C.

Electrification of the Long Island lines was undertaken on the low voltage d.c. system in 1905, and after trials with an 11-kV single-phase locomotive on a test track, it was decided to use the low-tension d.c. system for the approach lines on the Jersey City side of the river and through the tunnels, and electric working began in 1910 from a junction named Manhattan Transfer on the Washington main line. This short d.c. conversion helped to solve the worst of the Pennsylvania's immediate troubles, but was not extended, although the purely suburban routes of the L.I.R.R. were extended from time to time until they now cover a route mileage in excess of 140 with a corresponding track mileage of 450.

Single-Phase Beginnings

The a.c. system tested in 1908 had shown promise, and when some half-dozen years later the congestion round Philadelphia was becoming acute, it was decided to electrify the Philadelphia (Broad Street)—Paoli line, 20 miles long, on the 11-kV 25-cycle principle, using multiple-unit trains to ease considerably the movements at Broad Street dead-end station. The general results of this electrification, opened in 1915, were satisfactory, and the Philadelphia electrified suburban system was extended by the conversion of the Germantown and Chestnut Hill line in 1918, the Whitemarsh branch in 1924, the West Chester branch and the main line south as far as Wilmington in 1928, and the Norristown branch and northern main line as far as Trenton in 1930. New suburban passenger stations at Broad Street and West Philadelphia were opened in 1930 as part of the northern main line conversion.

Actually a low-voltage d.c. electrification in the Philadelphia neighbourhood had been carried out much earlier, in 1906, by one of the Pennsylvania's subsidiaries, the West Jersey & Seashore Railroad, from Camden to Atlantic City. This conversion was admittedly a try-out as to the traffic-building ability of an electric line, and it does not appear to have maintained completely successful results, for it now extends only as far as Millville.

Main-Line Conversion

Before the work on the Trenton extension was very far on the way it was announced that electrification would (*a*) be carried northwards to join with the New York electrified area at Manhattan Transfer, to convert the d.c. system there to a.c., and to carry on the electrification over the New York Connecting Railroad *via* Hell Gate bridge to Port Morris ; (*b*) be extended west from Philadelphia along the Harrisburg main line as far as Atglen and the freight cut-off lines joining in at Columbia. The work was to be undertaken progressively over a number of years. Some of the principal factors influencing the decision to electrify were the high, and increasing, density of passenger and freight traffic, and the proved ability of electric traction to deal efficiently and economically with such traffic ; and the desirability of new and more convenient stations at Newark and Philadelphia.

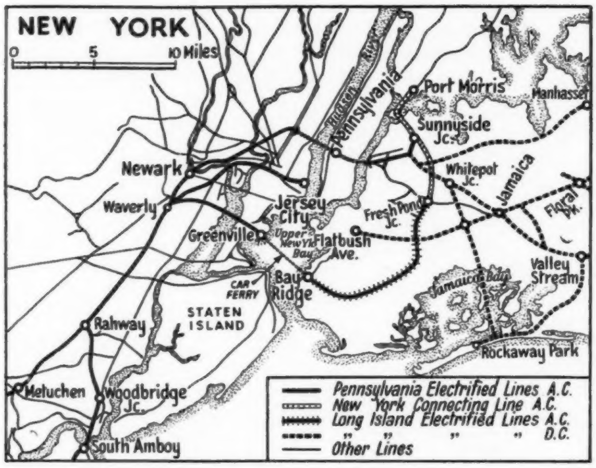
In the autumn of 1929, as a result of arrangements for the improvement of the main-line layout through the city of Baltimore, an extension of the above-mentioned scheme was sanctioned to cover the line from Wilmington to Washington and the freight line from Washington on to the Potomac yard.

The first part of the complete schemes authorised in 1928-29 to be undertaken were the 13 route (85 track) miles of low-voltage d.c. from Manhattan Transfer through the tunnels and Manhattan Island to Sunnyside yard, over most of which the traffic was so dense that conversion work could be carried on for only six hours a day. Because of the Long Island trains, many of these tracks still had to be used by a.c. and d.c. trains. Single-phase operation began in January, 1932, and in January, 1933, a through electric service was inaugurated between New York and Philadelphia. In March and April of the same year, electric operation of main-line trains also began between Philadelphia and Wilmington and Philadelphia and Paoli. Through electric services further south to Washington were introduced on February 10, 1935, and the complete change-over was achieved during the next eight weeks ; additional tracks for freight service over various portions of the main line between New York and Washington were electrified in 1935-36.

Westward Extension

Finally, in January, 1937, electrification of the passenger and freight lines west of Paoli as far as Harrisburg *via* Lancaster was sanctioned, and included the freight line from Morrisville (near Trenton) to Enola yard (Harrisburg) *via* Columbia ; the freight line following the course of the Susquehanna river from Columbia to Perryville ; and the freight line from Monmouth Junction to South Amboy, with the necessary freight and passenger yards and sidings. The project included also the freight yards at Pavonia, N.J., and South Philadelphia, and extension to electrification in yards at Trenton, Chester, Philadelphia, Linden and other towns. The financing of this project, comprising 315 route miles (773 track miles), was by a bond issue of $52,670,700. Its completion has brought the single-phase electrified route mileage of the Pennsylvania up to a total of 688 and the track mileage to 2,116. Electric passenger train operation to Harrisburg began on January 15, 1938, and since that time the freight lines have been brought under electric operation gradually.

Financing of the programme of 1928-29 was obtained through the railroad's own resources and ordinary bonds, but in the early thirties the general economic situation had brought normal investment almost to a standstill. Co-operating with the government in an effort to promote employment, the Pennsylvania in the latter part of 1933 obtained $80,000,000 through the Public Works Administration by the sale to the government of secured obligations



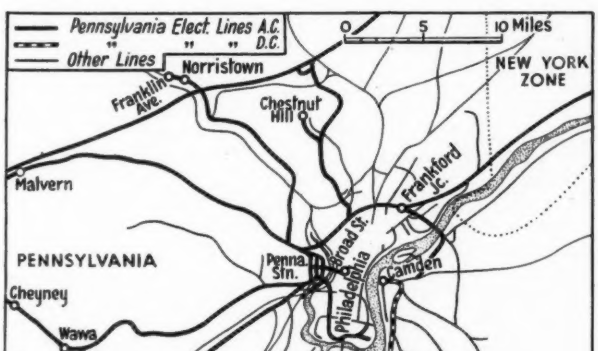
Map of electrified lines in the New York area belonging to the Pennsylvania Railroad and its associates

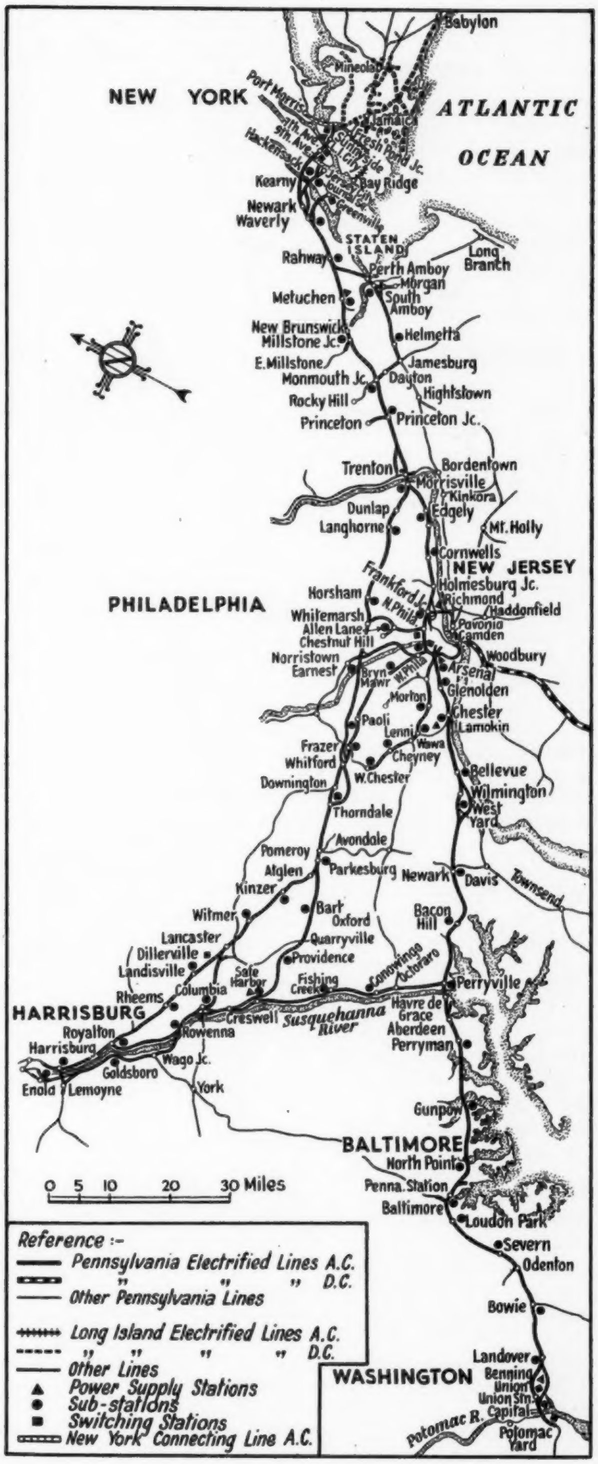
maturing in periods of 10, 15, 20 and 30 years. Much of this money was devoted to the completion of the Wilmington—Washington electrification and to the construction of 101 new electric locomotives. The Harrisburg extension was financed by railroad bonds as already described.

Ancillary Works

A good deal of preparatory and special work was required in connection with the main line electrification schemes, principally in connection with the layout of lines through Philadelphia, Baltimore and Washington; the number of draw and lift bridges along the route; the Baltimore tunnel, a mile and a half long; and the location of the e.h.t. supply cables through the cities of Washington and Baltimore. New stations, or considerable modifications, were also needed at various points.

Improvements at Newark comprised a new station and three vertical lift bridges over the River Passaic. The largest of these bridges has a span weighing nearly 2,000 tons which is lifted by 111 ft. to give a clear channel height of 135 ft., the lifting speed being 2 ft. a second. The bridge is passed by a large number of vessels and crossed by an intense train traffic running over three tracks; the electrical operation is from two sources of





Above: Map of the Pennsylvania a.c. and d.c. electrified routes, covering main-line and suburban systems

Left: Map of electrified lines in the Philadelphia area belonging to the Pennsylvania Railroad and its associates

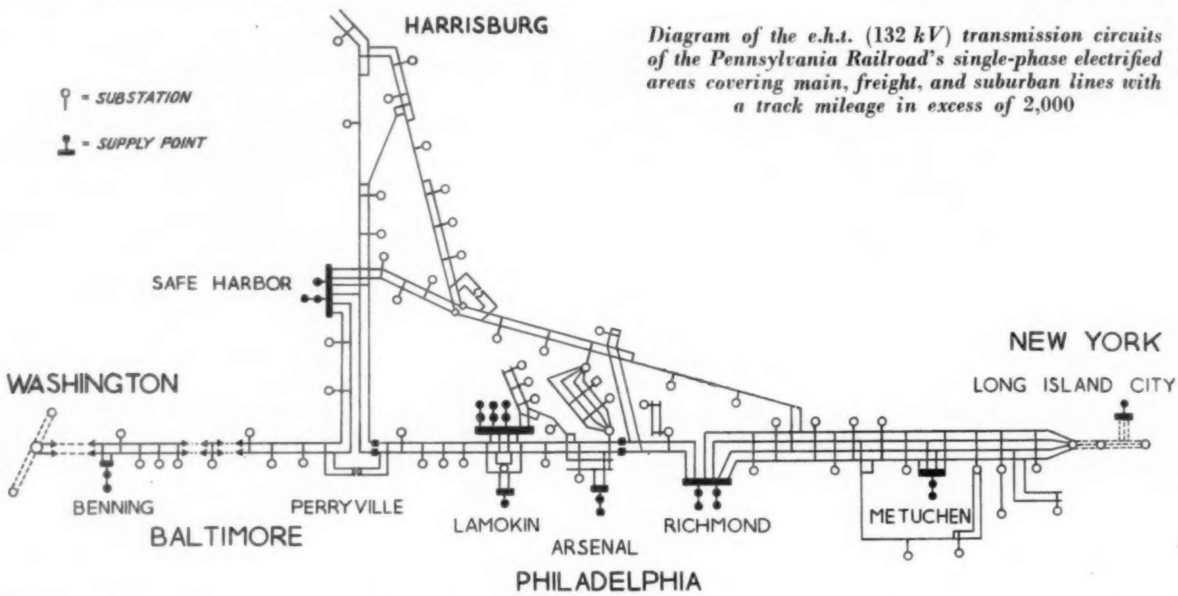


Diagram of the e.h.t. (132 kV) transmission circuits of the Pennsylvania Railroad's single-phase electrified areas covering main, freight, and suburban lines with a track mileage in excess of 2,000

single-phase 11-kV 25-cycle supply feeding 750-h.p. motors. The new station at Newark has eight 1,100-ft. passenger platforms and has transfer arrangements for passenger traffic to the Hudson terminal in down-town New York.

Considerable attention had to be given to the signalling and track circuiting in the New York area, where a.c. and d.c. trains use the same tracks. The presence of both types of current in large volumes in the track rails and the passage of d.c. through the transformers on locomotives, motor-coaches and substations necessitated careful checks to ensure that the fourth harmonic present in the 25-cycle current waves did not combine with the currents of the signal system of a nominal frequency of 100 cycles a second. Alterations had to be made in tunnels to gain sufficient clearance for 11 kV to earth, and communication circuits had to be buried in conduit. In the early Philadelphia—Paoli line the three-phase supply was at 44-kV, but from 1928 onwards successive extensions were fed at 132 kV, and where these e.h.t. feeders were run in underground cable through the cities of Washington and Baltimore special investigations had to be made to increase the experience available with very high-tension circuits buried below ground level.

Power Supply

The Pennsylvania single-phase system as now existing is supplied with current at eight points, viz., New York (from the railroad's Long Island City plant), Metuchen, Richmond, Arsenal(Chester), Lamokin(Philadelphia), Perryville, Benning, and Safe Harbor. The aggregate transformer capacity at the supply points is 452,500 kVA plus the equipment at Safe Harbor supplying the Harrisburg lines. Apart from the Long Island supply and part of that from Safe Harbor, the energy is obtained from supply authorities through 60/25-cycle frequency-changer motor-generator sets from interconnected 60-cycle networks. The supplies are generally operated in parallel through the Pennsylvania 25-cycle lines and through the supply authorities' own 60-cycle lines, and are split only when the 60-cycle systems are out of step, or if there is a possibility of this occurring through lightning storms.

Cables from the 25-cycle generators connect through circuit-breakers to a 13·2-kV tubular ring busbar divided into sections by means of busbar tie circuit-breakers. From these sections feeds are taken through circuit-breakers to the transformers, which themselves are connected direct to the transmission lines through horn-gap sectionalising switches. Oil circuit-breakers on the ring busbar in these supply stations have a continuous rating of 5,000 amp. and an interrupting rating of 120,000 amp. The transformers in the Long Island City power plant feed into the distribution system of the New York terminal area at 11 kV, and this system in turn is connected to the 132-kV system by transformers at Hackensack Portal substation.

Circuit breakers are provided at three points in the 132-kV system to isolate the areas served by the principal supply stations. The breakers located at Perryville and Lancaster serve to isolate completely the two main power supply systems, the first of which covers the area from New York to the Susquehanna river and westward to a point between Lancaster and Paoli, and the second the area south from the Susquehanna river to Washington and from the western sectionalising point to Harrisburg and the Enola yards. The third set of breakers is at the Zoo substation in Philadelphia and isolates the power supplies to the north of the city from those to the south. When these breakers are opened, phase-breaks are opened in the contact system at the same substation to prevent the momentary tying together by trains of contact lines fed from separate sources which may be out of phase.

Prior to the Harrisburg extension, automatic operation of the 132-kV breakers was not provided for short circuit or ground faults on the Pennsylvania's transmission lines, but because of the greater length of the circuits consequent upon the latest extension, automatic operation is now provided ; it reduces the length of circuit tripped out by the faults, and in the event of short circuits the principal supply points are segregated to prevent such a fault becoming a sufficient shock to the system to cause instability.

In the case of ground faults the line affected is relayed to trip first the sectionalising breaker in that line only, and then the section of the line at fault is isolated completely. In the event of a short circuit the relaying provides that the sectionalising breakers both on the paralleling line and the line at fault are tripped, excepting at Philadelphia Zoo substation, where tripping of the sectionalisers was not considered necessary. After the sectionalising breakers have opened the section of line at fault is isolated completely.

The railroad's 132-kV transmission line conductors are carried on the catenary system masts and supported 8 ft.

(*Continued on page* 37)

MULTIPLE-UNIT ELECTRIC TRAINS

Abstract of a paper read before the Institution of Locomotive Engineers on March 13 by Mr. H. H. Andrews. The paper was followed by a most interesting discussion in which two Chief Mechanical Engineers, a Deputy C.M.E., and an ex-C.M.E. took part; a précis of the discussion will be found at the end of our abstract of the paper.

CONTROL gear may be divided into two types, in one of which the contactors consist of unit switches and in the other of switches operated by the motion of a camshaft. The unit switch type may be either electro-magnetically or electro-pneumatically operated, the modern tendency being towards electro-pneumatic operation.

In the case of switches operated by a camshaft, the camshaft itself may also be operated either electrically or electro-pneumatically. With the unit switch type it is necessary for the contactors to be fitted with auxiliary contacts to ensure the correct sequence of operation, and all contactors are fitted with blow-outs because any one contactor may on occasion be called upon to break current.

With the camshaft type the sequence of operation is mechanical, and as this is positive in operation in all cases, individual switches do not need interlocks and only one or two of them require blow-outs, but the operating gear of the camshaft, whether electric or electro-pneumatic, requires a motor or air engine, with its gearing, and a drum-type switch fixed to the camshaft to provide the necessary control of its movement, and which takes the place of the interlocking contacts on the unit switch type.

Protective Apparatus

Protective apparatus with electrical equipment has to serve two purposes: protection against overload and protection against defect. Protection against overload is by means of an overload relay which will trip the line switches and cut off the power immediately a specified current is exceeded. Protection against fault can be effected by means of a high-speed circuit-breaker which has a given current setting and operates practically instantaneously; by an ordinary circuit breaker, which again has a definite current limit, but opens in a perceptible portion of a second; or by an overload relay and line switch, which again operate at a pre-determined value and are somewhat slower than an ordinary circuit breaker or a fuse with a time limit varying with the current.

The modern tendency is to provide protection on the motor-coach itself in its simplest form, namely, the overload relay and line switch. The supply to the overhead line is sectionalised from the substation, and each substation section is provided with a high-speed circuit-breaker, which on a fault occurring will cut off the power even before the overload relay and line switch on the coach come into operation.

Motors

It is clear that there is no difficulty in building a 1,500-volt motor to operate on a 1,500-volt line, as such motors are used on a 3,000-volt line, but except for large units of 300 h.p. and over, a motor built for operating at 750 volts and insulated for 1,500 volts is a smaller, lighter and more economical proposition than one wound for 1,500 volts.

There is no theoretical impossibility in manufacturing a motor to the full line voltage, but with increase in voltage the motor becomes larger and heavier as there is a definite limitation to permissible voltage drop between commutator segments and to width of segments; thus the diameter of the commutator increases as the voltage is increased, and this in turn affects the dimensions of the motor and the driving wheel. Further, as the line voltage is increased, the insulation of the coils to earth and the surface creepages must be increased, both having the effect of increasing the motor dimensions. The combined effect means that the higher the motor and line voltages the greater will be the weight per h.p.

It is difficult to establish a definite ratio showing the manner in which line voltage, and commutator voltage affect the weight and size of motors. Broadly speaking, it may be taken that for motors up to 250 h.p., other conditions being equal, a motor wound for 750 volts and insulated for 1,500 will be somewhat larger and heavier than a 600-volt motor, owing to additional creepage surface being required for the coils, commutator and brush gear. A motor wound for 1,500 for operation on a 1,500-volt line will be appreciably larger, as a bigger diameter commutator, and consequently armature core, will be required. As the h.p. of the motor is increased, the proportional difference between the above types decreases, and for motors of 325 h.p. and over, motors wound for 750 volts or 1,500 volts will not vary appreciably. On 3,000 volts operation motors of a given horse-power and requirements will be larger and heavier than those for 1,500 volts, the weight increase being from 20 to 25 per cent.

Weight Saving

The provision of specially light stock with electric working is a problem of economics. The question of weight reduction of the non-paying load is not confined to ultra high-speed long-distance trains, and for electric stock operating at high rates of acceleration it is an important one throughout the entire range of operation. With trains hauled by locomotives there is not much difficulty in regard to the weight of the propelling machinery, for this provides a necessary part of the adhesion. But with a motorised train the weight of the electrical equipment carried on the coaches quite naturally becomes the target for weight reduction.

The motors represent from 55 to 65 per cent. of the total weight of equipment, and therefore offer the most promising field for weight reduction. On the original (1904) Liverpool—Southport electric trains the 150 h.p. motors with gear and gearcase weighed 6,050 lb., or 40 lb. per h.p. On the new equipments which the L.M.S.R. has put into service on the same line a 235 h.p. motor weighs 4,484 lb., or 19 lb. per h.p. In 1931 a well established electro-pneumatic contactor rated at 300 amp. for 1,500-volt operation weighed 85 lb. By 1937 the aggregation of minor improvements had reduced this by 12½ per cent. to 75 lb. As ten or more contactors are used per equipment, a saving of at least 100 lb. has been effected. A more startling reduction has been made on a 600-volt contactor, also rated at 300 amp., improvements in design having reduced this from 85 lb. to 31 lb. Electromagnetic contactors are still used for a number of auxiliary purposes. A typical contactor of this type has been redesigned over about the same period, the weight being changed from 29 lb. to 17 lb. The weight of air-operated pantographs has been reduced from 1,000 lb. to 750 lb. between 1924 and 1938. The development of the continuous strip type of resistance as an alternative to the cast iron type offers

CHARACTERISTICS OF MULTIPLE-UNIT ELECTRIC TRAINS

	L.M.S. Euston—Watford	L.M.S. Liverpool—Southport	L.M.S. Wirral	L.N.E.R. Tyneside	S.R. 2-coach	S.R. 3-coach	S.R. 4-coach express	N.Z.G.R.	Central Brazil	French State
Composition of unit ...	MC — T — DT	MC — T — DT	MC — T — DT	MC + DT	MC — DT	MC — T — MC	MC — T — T — MC	MC — DT	DT — MC — DT	MC + MC
Gauge	4 ft. 8½ in.	4 ft. 8½ in.	4 ft. 8½ in.	4 ft. 8½ in.	4 ft. 8½ in.	4 ft. 8½ in.	4 ft. 8½ in.	3 ft. 6 in.	5 ft. 3 in.	4 ft. 8½ in.
Tare weight of unit (tons)	114	88·7	77·15	56·15	73	109·5	160	67·4	124	75
Tare weight of M.C. (tons)	56	41·3	35·8	—	43	43	47	43	56	—
Overall length of unit (ft.)	184	209	177	112	129	193	265	123	196	132
Number of passenger seats	280	268	181	128	159	226	226	132	212	132
Gross weight of unit (tons)	131·5	105·5	88·45	64·25	82·95	123·6	174·1	75·7	137·3	88·3
Nominal line volts ...	600	600	650	600	600	600	600	1,500	3,000	1,500
Number of motors per unit	4	4	4	2	2	4	4	4	4	6
One hour rated H.P. per motor	280	235	135	216	280*	280*	225*	165	175	235
Type of control gear ...	EM Contactor	EP Contactor	EP Contactor	EM Contactor	EP Contactor	EP Contactor	EP Contactor	EP Contactor	EP Contactor	Elec. Camshaft
Mounting of control gear...	Cab	Undercar	Undercar	Undercar	Undercar	Undercar	Undercar	Undercar	Undercar	Undercar
Weight of elect. equip.— M.C. (tons)	22·2	13·3	11·65	8·05	10·53	10·53	9·6	13·0	17·0	24·0 ap-prox.
D.T. (tons)	1·2	1·25	1·05		9·25	—	—	0·75	1·0	
N.D.T. (tons)	0·7	1·95	0·8	—	—	0·34	0·56	—	—	
Total weight elec. equip. per unit (tons)	24·1	15·6	13·5	8·05	11·455	21·4	20·3	13·75	19·0	—
Adhesive weight per motor (tons)	14	10·325	8·95	12·1	12·525	12·525	13·45	10·75	14·0	12·5
Mean accelerating T.E. per motor (lb.) ...	4,870	4,480	3,250	3,700	4,420	4,420	2,450	3,950	5,300	2,420
Average rate accel. (loaded) m.p.h.p.s.	1·3	1·5	1·3	1·0	0·91	1·23	0·455	1·35†	1·37	1·47
Average distance between stops (miles)	0·98	1·23	0·94	1·06	3·2	1·0	18·6	0·935	0·65	13·5
Average speed (m.p.h.) ...	29·8	33·3	26·3	23·0	32·3	24·0	46·1	26	21·5	57·5
Tare wt. of unit incl. elect. equip. per ft. run (tons)	0·625	0·428	0·442	0·5	0·57	0·57	0·6	0·55	0·64	0·57
Tare wt. of unit excl. elect. equip. per ft. run (tons)	0·48	0·35	0·36	0·43	0·475	0·46	0·528	0·44	0·54	0·385‡
Weight of motor per h.p. (lb.)	28·0	19·1	30·5	25·0	—	—	—	26	33·8	38·0
Weight of control gear (M.C.) per h.p. (lb.) ...	16·5	12·6	17·5	16·7	—	—	—	19·15	21·2	
Per cent. elect. equipment to tare (unit)	39·5	17·5	17·5	14·3	15·7	19·8	12·7	20·5	18·2	32·0
Per cent. elect. equipment to tare (M.C.)	21·25	32·0	32·5	—	25·6	25·6	20·5	30·5	34·5	
Ratio mean accel. T.E. to adhesive weight... ...	15·5	19·4	16·3	13·6	15·5	15·5	8·2	16·5	17·0	8·6

* Motors totally enclosed. † On 2½ per cent. grade. Same acceleration on level with second setting on current limit relay.
‡ Including air-conditioning apparatus

a substantial saving of weight. On three modern schemes comparison of the strip type with cast iron shows the following, the ratings being identical :

Voltage	Strip Type	Cast Iron
600	480 lb.	1,034 lb.
1,500	1,120 lb.	2,590 lb.
3,000	1,008 lb.	3,180 lb.

On the latest motor-coach systems care has been taken to ensure that the adhesion of the motored wheels is utilised fully up to the safe limit. Any reduction in the weight of the equipment in the motor-coach must be balanced by a reduction in the hauled weight, unless acceleration is to be sacrificed. For example, in a three-coach train with a tare of 100 tons made up of a motor-coach of 45 tons and two trailers, each of 27½ tons, the weight of the electrical equipment in the motor-coach will be 13½ tons, and the total weight of the electrical equipment in the train about 15 tons. A reduction in the electrical equipment weight of one ton obviously reduces the adhesion, and consequently the torque permissible for acceleration by 2·25 per cent. To retain the same rate of acceleration the train weight must be reduced by 2·25 per cent., and the whole of this weight must come off the trailers. The weights would then become motor-coach 44 tons, and two trailers 26·375 tons each. As a side issue, under the conditions mentioned above, if it were possible to reduce the weight of the electrical equipment or the motor-coach by one ton, the total power saving would be effected not on one ton but on 3¼ tons, against which would have to be set any increased cost of equipment and trailers.

* * *

Mr. C. E. Fairburn, in opening the discussion, said that the paper gave a very good summary of the stage reached by electric traction. As regards progress made in motor design he did not hand out any bouquets to the motor designer. Much of the improvement made during the last 40 years had been due to the ingenuity of the manufacturers of auxiliaries, such as insulation. Within the past few years gears also had improved enormously. Quill drive for d.c. motor-coaches was too expensive, and had no particular advantage. In single-phase traction the quill helped the motor in starting ; there was no difficulty in this direction with a d.c. motor, so part of the advantage of a quill was lost immediately. Clean air was absolutely essential for efficient motor operation. On the Wirral stock of the L.M.S.R. the ventilating louvres were above

the waist, but the muslin filters within them showed that a good deal of metal dust was taken up; therefore, in the Liverpool—Southport stock the motor-ventilating duct had been led up to the roof. By using copper conduit instead of steel a weight saving of 375 lb. had been made on one of the Wirral motor-coaches. On the Liverpool—Southport stock five motor-coaches and five trailers had been given copper conduits, and compared with steel a weight saving of 1,254 lb. had been effected in a unit made up of one motor-coach and one trailer. By applying copper air piping for the brake system, the weight saving for the two-car set had been raised to 1 ton. In view of the great initial cost of a conversion scheme one of the main essentials in the operation of an electric line was to keep the capital moving. The number of breakdowns must be kept to the absolute minimum, but if one occurred the object must be to clear it as quickly as possible. It could not be considered sound engineering if a defect in a contactor costing £15 put out of commission a three-car train costing £15,000. The equipment ought to be so designed and arranged that a defect to any detail did not keep the train in a depot longer than an hour or so.

Big Motor Proportions

Mr. Besant drew attention to the low weight of the traction motor used in the Sydney suburban stock of the New South Wales Government Railways. Although this motor had been designed about 15 years ago it had a lower specific weight than any other motor in the table except the ultra-modern type fitted to the Liverpool—Southport coaches. The complication of control systems, particularly as regards the electric interlocking, was a matter that needed serious attention, because simplification was urgently needed.

Mr. W. A. Stanier said that electrical engineers always compared very modern electric stock with very old steam locomotives. If a comparison was made with up-to-date steam equipment he doubted whether there was very much in the saving normally attributed to electric traction. A well-designed steam locomotive had a wide range of efficiency. As regards trailing loads double-heading was not necessary in England even with trains of 600 tons weight. Designers of steam stock had produced very good designs of electric stock, to wit, the Liverpool—Southport trains, the design of which was the result of a happy combination of good electrical and mechanical engineering.

Motors, Ventilation, and Make-up

Mr. W. S. Graff-Baker drew attention to Mr. Andrews' remark about the use of sleeve bearings where the motor was suspended on the axle. Roller bearings were used throughout the train for the axleboxes and for the armatures, and it seemed absurd to use plain sleeve bearings between the motor and the axle, which would require attention every three or four days although all the other bearings could run for six months to a year without attention. Forced ventilation of the traction motor was very difficult to use satisfactorily if sharp curves were encountered, because of the play required by the bellows. In certain cars in the U.S.A. forced ventilation had been adopted on the assumption that as the usual self-ventilating fan on the armature was inefficient the horse-power absorbed by it could be used to greater benefit in driving a separate blower; a special form of rotor had been adopted in order to get rid of the dirt in the air before it reached the motor. In Mr. Graff-Baker's opinion no electrical equipment should be used above the floor in a multiple-unit train. Such an arrangement not only restricted the space available for passengers, but also raised the centre of gravity to a height which seemed undesirable. The latest forms of camshaft control were not so complicated as Mr. Andrews had inferred. Regarding the figures given in the paper as to the weights of a typical three-coach train in which the motor-coach weighed 45 tons and the two trailers 27½ tons each, Mr. Graff-Baker felt that this was equivalent to using a locomotive in which some people rode very uncomfortably and two coaches in which people rode reasonably comfortably. It would seem advisable to use more motors of a smaller capacity, distributing them down the train and letting everyone travel more comfortably.

Early District Schemes

Mr. Gilbert Scott referred to the early history of electrification on the Metropolitan and District Railways, and said that considerable discussion had taken place as to whether d.c., single-phase, or three-phase traction should be adopted. At the height of the discussion certain American interests quietly bought up a large proportion of the shares, and with their assumption of control insisted that the conversion should be undertaken on the low-tension d.c. system with multiple-unit trains as originally evolved by F. J. Sprague and developed in the States. This coming in of American interests certainly did the District Railway and London transport a lot of good compared with what the position would have been today if the three-phase system proposed by Ganz had been adopted.

Other members who took part in the discussion were Mr. J. P. Maitland, who commented on the frequent complaints about the uncomfortable riding on large motor-coaches and the great desirability of reducing the unsprung weight which had led to a considerable augmentation of track troubles; Mr. C. B. Unwin, who drew attention to the more than negligible temperature coefficients of strip resistances compared with that of the cast iron block type; Mr. Moon, of the L.M.S.R., who supplemented Mr. Andrews' information on the weights of multiple-unit trains by quoting the Budd twin-car sets on the French National Railways as weighing 0·36 tons per seat as against the Liverpool—Southport trains weighing 0·28 tons per seat.

Mr. H. H. Andrews, in a brief reply to the discussion, said that as far as he knew the motors fitted to the Sydney suburban stock were the biggest used in multiple-unit traction. The armatures were approximately 24 in. in diameter, but the relative weight values he had quoted for 1,500-volt and 750-volt motors began to be inoperative at an armature diameter of 18 in. He was glad to hear of the simplification in camshaft control which had been achieved in the equipment mentioned by Mr. Graff-Baker, but at the same time many modern multiple-unit trains, for example the Budd sets in France, still had very complicated interlocking.

Pennsylvania Railroad Electrification

(*Continued from page* 34)

from the poles on cross arms. The insulator strings are composed of nine standard 10-in. suspension units. Each of the two wires of a circuit is normally at a balanced potential of 60 kV to ground, inasmuch as the midpoint of the 132-kV step-up transformer windings are grounded through 330-ohm resisters at the supply points. The conductors are either 250,000 c.m. hollow copper cable or 477,000 c.m. aluminium cable steel reinforced. In general, each substation is supplied by two or more transmission circuits. A No. 4/0 stranded copper ground wire is carried on top of the poles about 12 ft. above the upper transmission wires.

(*To be continued*)

NOTES AND NEWS

Italian D.C. Electrification.—The Genoa(Brignole)—Viareggio main line, which is now being converted from 3,700-volt three-phase to 3,000-volt d.c., is to be equipped with electric signalling of the automatic block type.

German Double-Bogie Locomotives.—The one hundredth standard Bo-Bo locomotive on the 15-kV $16\frac{2}{3}$-cycle single-phase system of the Reichsbahn has been placed in traffic. In the latest form the weight is 78 *tonnes* and the one-hour output 2,080 kW.

Swedish Conversion.—An accelerated rate of conversion of the Laangsele-Boden line of the Swedish State Railways is proposed in a scheme now being considered by the Swedish Riksdag, which is being asked to sanction an increase from 8,000,000 kr. to 16,000,000 kr. as the amount to be spent on this work during 1940.

Latvian Electrification Project.—The Latvian State Railways have drawn up a scheme for the conversion of the Riga-Ieriki, Riga-Krustpils, Riga-Jelgava, and Riga-Tukums lines to electric traction. These routes are said to carry about half of the total passenger traffic and a third of the freight traffic on the State system. The opening of a new hydro-electric station at Kegums and the shortage of coal during the last six or seven months are believed to be responsible for the project.

Electrification Commission.—Railway electrification in Spain is to be the subject of consideration in future by a Comision de Estudios y Proyectos de Electrificacion de Ferrocarriles, appointed by a Ministerial Order published in the Madrid *Boletin Oficial* of March 6. The Commission will be charged with the preparation of a general plan relating to all existing and proposed schemes and will advise the Government on possibilities of extension and standardisation.

M.S.J.A. News.—Some new carriages have been brought into use on the Manchester, South Junction & Altrincham Railway, and have been inserted in some of the three-car formations between the motor-coach and composite trailer; they are nine-compartment third class non-driving trailers. Trains in the rush hours now comprise one three-car and one four-car sets, and the four-car trains are sometimes used during slack periods. The additional car seems to make little difference in the acceleration.

Victorian Railways System.—According to the report of the Victorian Railways for the year ending June 30, 1939, the 12 electric locomotives in that period covered 207,560 miles (86,000 in shunting service), and the electric motor coaches 7,621,595 miles. The 856 electric motor-coaches and trailers operating the Melbourne suburban traffic covered 38,214,656 vehicle miles, equivalent to 1,440,477,509 gross ton-miles. Newport power station generated 182,686,931 kWh during the year, and in January, 1939, a £290,000 order was placed for new boilers. Tests with wax graphite lubricating compound for the pantograph pans of the multiple-unit trains were made on the Box Hill and Clifton Hill lines, and results indicate that a longer life may be expected than with the normal grease lubrication.

Swedish Electrification Statistics.—According to a recent communication by Mr. Ivan Ofverholm, Chief Electrical Engineer, the Swedish State Railways had by August, 1939, electrified 3,676 route km. and had under conversion a further 499 route km. When the existing programme was complete, the 4,175 route km. worked by electric traction would represent 56 per cent. of the length of the State system and would carry 90 per cent. of the whole traffic. Up to August last a total of 327,920,000 kr. had been granted for electrification, equivalent to 78,550 kr. per route km. including rolling stock. The current consumed during 1938 amounted to 545 million kWh, at a cost of 10,712,000 kr. A total of 473 electric locomotives was in traffic at the end of 1938, and during that year they ran 42,000,000 km.

Swiss Rack Railway Modernisation.—Three modern lightweight motor-coaches have just been introduced by the Bex-Gryon-Villars-Chesières Railway, a metre-gauge line connecting with the Swiss Federal system at Bex, on the Simplon main line. In conjunction with improved operating methods, these coaches have enabled a faster and more frequent service to be provided and bus competition countered. In general design the cars are similar to those of the Rochers de Naye Railway, illustrated and described in our issue of August 19, 1938. They tare $17\frac{1}{4}$ tons and have two 125 h.p. motors. Mixed rack and adhesion equipment is fitted and up the 1 in 5 Abt rack section a speed of 9·3 m.p.h. can be maintained; on the adhesion section the normal top speed is 18·6 m.p.h. The new coaches are fitted with pantographs, but must work in with older cars and locomotives equipped with trolley wheels. Electrification is on the 650 volts d.c. system. A reduction in overall journey time from 78 to 45 min. has been made possible by the new stock.

LETTER TO THE EDITOR

(The Editor is not responsible for the opinions of correspondents.)

Liverpool—Southport Trains

Southport
March 11, 1940

TO THE EDITOR OF THE ELECTRIC TRACTION SUPPLEMENT

SIR,—In your February 2 issue you state that the new coaches on the Liverpool—Southport trains are designed to travel up to 70 m.p.h. I wonder whether this indicates that new timings are to be arranged, as at present even the old stock is too fast for the schedules. In my experience an unchecked run by an express is unknown, because of the absurd timings, *e.g.*, expresses leave Liverpool two minutes after a stopping train, and therefore must run on half power for the first two miles, or come to a stand at Sandhills as four tracks are not available until Bank Hall. Again the 5.20 p.m. ex-Southport is express, calling at three stations only, yet it is timed to take as long as the 5.26 calling at all 14 stations! The result is that although not stopping at the stations it stops between them!

I do think that automatic signalling would be essential from Liverpool as far as Hall Road if express running is really attempted, especially up to 70 m.p.h. Numerous level crossings rule out automatic signalling at the Southport end.

EDWARD HILL

[We believe it was the intention of the L.M.S.R. to introduce completely new timetables with rearranged and considerably accelerated schedules when all the new stock was delivered, but the war has put back the adoption of the proposals.—ED.]

Electric Railway Traction

LOCOMOTIVE AND RECTIFIER OPERATION IN S. AFRICA

FREIGHT trains of 850 tons are hauled over the Natal main line by three locomotive units up rising gradients of 1 in 40 and 1 in 30 with numerous curves of 330-ft. radius at an average speed of 22·9 m.p.h. Regenerative braking, as the safest, most effective, and most economical form, is used for trains of coal and manganese ore going down these gradients. Loads as heavy as 2,000 tons are hauled by three units under the control of one driver, and on a ruling grade of 1 in 50, loads of 1,500 tons are handled with the greatest possible safety.

The locomotives responsible for these performances, and of which there are 165 in service, were, with three exceptions, manufactured by the Metropolitan-Vickers Electrical Co. Ltd. These locomotives are equipped with two articulated bogies, each axle being driven by an axle-hung traction motor of 300 h.p. continuous rating, making a total h.p. of 1,200. The maximum safe motoring speed is 45 m.p.h. and each locomotive weighs about 66 tons complete. A description of the latest model will be found in the issue of this Supplement for July 23, 1937.

The electric locomotives are designed for multiple-unit operation from the leading locomotive, and two or three are coupled together and controlled by a single driver. Thus the greatest economy of unit operation is possible by avoiding the use of larger and more powerful locomotives. Operating conditions in South Africa are such that a locomotive of a larger type might be economically employed in one direction, but in most cases it would not be possible so to employ it in the return direction. Multiple-unit operation almost entirely overcomes this difficulty and enables the maximum operating value to be obtained from each locomotive with a minimum of manpower. The normal availability is 23 hr. a day.

In the early days of electric traction in South Africa, some difficulties were experienced in ensuring that units which were working in a set would share regenerated output equally. Machining and accurate bedding of all contacts in the cam groups were found to be necessary, and compensation for variations in wheel diameter on different units was made by the introduction of an adjustable resistance in the field circuit of the exciter motor-generator set, which enables a fixed standard of field circulating current to be established.

The original control arrangements for entering regeneration on a down grade relied largely on the skill of the driver. Under practical conditions the driver would, before closing his line switches, notch up the regeneration handle to the required position according to the grade being negotiated and the load being hauled. Under these conditions a certain amount of train jerking was unavoidable, but later units were designed with an improved method of entering regeneration, embodying duplicate voltmeters, one of which registers line voltage and the other regenerated voltage. All locomotives have since been adapted to the new arrangement, and under present conditions the driver notches up the regeneration lever until both voltmeters read the same voltage, when the line switches are closed with a complete absence of train-surging or jerking.

Not only does regeneration provide the safest and most efficient form of braking possible, but the economy effected will be appreciated when it is stated that tests with precision instruments have shown the proportion of regenerated energy to be as high as 36 per cent. of the consumed energy. The actual saving to the administration from the regenerated current integrated at substations in Natal during the year ending April, 1938, was £22,100, and for the following twelve months ending April, 1939, the figure was £17,326. These figures, however, represent but a small proportion of the total regenerated energy, as by far the greater portion—probably 80 per cent.—is consumed by other trains motoring in the section, thus reducing appreciably the number of purchased units of electricity, although it is practically impossible to ascertain this figure.

Finally, a feature of regenerative braking on electric locomotives which is of particular significance is that down gradients may be traversed at a higher average speed than can be done with mechanical braking without in any degree impairing the safety. Furthermore, the driver may select any desired speed between given limits and, on setting the controls, regeneration will hold the train at that speed constantly, irrespective of changes in grade and curvature, until the train reaches the bottom of the gradient, and as regenerated current falls off the units will automatically motor the train.

Of the electric locomotives now operating on the S.A.R., no less than 20 per cent. have registered well over 1,000,000 miles of service each, and a monthly mileage of over 14,000 per locomotive is not uncommon. All locomotives are controlled from and maintained at one depot—Danskraal—where not only routine inspections, but also major overhauls of the electrical equipment are effected. Maintenance costs average 2·55d. per unit-mile.

Rectifiers

The experience of over three years' regular service has shown that, though the installation of inverted rectifier equipment does involve more problems than an ordinary rectifier system, nevertheless with careful engineering the largest systems can be equipped with such substations, even under difficult conditions, with assurance of satisfactory operation in all respects.

Although five years have elapsed since these rectifiers were designed, their ratings per anode still exceed by a wide margin those of any other wide-range grid-controlled rectifiers or inverters known to be in service. The load factors given on page 51 show that these are not mere theoretical ratings, but that the plant has for a long time been working up to the limit of the loads for which it was constructed.

Two subsequent developments are of interest. Within recent months a connection has been added at Booth to permit tying in the 88-kV transmission line there with Congella (Durban) power station, and an extension now in progress is the electrification of the Rossburgh-Hillcrest line to serve the Durban suburban traffic. The Electricity Supply Commission ordered the rectifiers for this latter electrification during 1939, namely, four B.T.-H. rectifiers and all associated apparatus, substantially duplicates of the equipments described in this Supplement and installed on the Cato Ridge-Durban and Glencoe-Volksrust sections.

RECTIFIER EQUIPMENTS FOR REGENERATIVE WORKING

A detailed description of the requirements, design and operation of the B.T.-H. rectifier-inverter plants in the substations of the Durban-Volksrust section of the South African Railways

By J. C. READ, M.Sc., A.M.I.E.E.

TO increase the traffic capacity of the Natal main line of the South African Railways, an initial section from Pietermaritzburg to Glencoe was electrified in 1922-1926, as the combination of single-line working, steep gradients and sharp curves was rendering this section a bottle-neck for the whole line. A power station was built for the purpose at Colenso, about half-way along the electrified section, and twin 88,000-volt transmission lines were run north and south to supply the substations, the converting plant in which consisted of B.T.-H. motor-generator sets delivering 3,000 volts d.c. to the track. The locomotives were equipped for regenerative braking, the substation equipments being made suitable for returning regenerated energy to the a.c. system.

Smaller extensions to this electrified system were carried out in succeeding years, but it became clear that to secure the maximum economy of working it was necessary to extend the electrified main line section to the south as far as Durban, and to the north as far as the Natal border at Volksrust (see map, Fig. 1). Experience had shown that this extension could be carried out without enlarging the power station, and further savings of capital cost were to be expected by fabricating the track structures locally from scrap rails, by using only single 88,000-volt transmission lines for the extensions, and by employing mercury arc rectifiers instead of motor-generators in the substations.

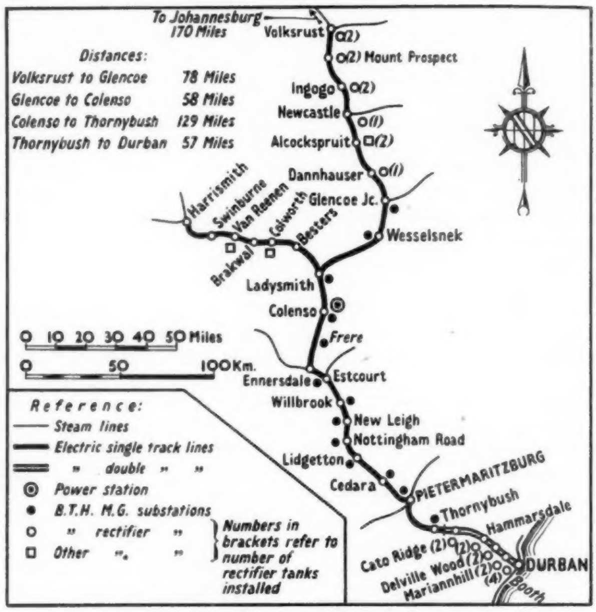


Fig. 1—Map of South African main-line electrified system in Natal

Adoption of Rectifiers

The use of rectifiers, although offering economies in first cost and efficiency as compared with 3,000-volt motor-generators, created the problem of how to absorb the current returned by regenerating locomotives. The traffic conditions and gradients in the new sections were such that the amount of energy regenerated at the substations would be large enough to justify the provision of apparatus for returning this energy to the a.c. lines. The Electricity Supply Commission therefore carried out a world-wide investigation into the state of development of grid-controlled rectifiers capable of returning energy from a d.c. system to an a.c. system, and it decided that sufficient progress had been made to justify the new substations being equipped with this type of plant.

The contracts for the substation equipments dealt with in this article, for these important main-line extensions to Durban and Volksrust, comprised 20 such rectifiers in all, together with the associated apparatus.

This constituted the first main line electrification to be equipped with inverted rectifiers in large numbers. In addition, some unusual local conditions (referred to later) were present, which rendered it a particularly severe test on the inverted equipments. Consequently a number of problems arose—and were successfully solved—such as are seldom met with in simple rectifier practice. All these equipments have been in regular use for over two years.

General Arrangement, and Conditions to be Met

It is well known that a grid-controlled rectifier can only be used as an inverter, to return energy from a d.c. to an a.c. system, by reversing the d.c. voltage at its terminals, not by reversing the direction of current flow. This is obviously so, since by its nature a rectifying device can only carry current in one direction. It follows that for reversible operation it is necessary either to employ d.c. reversing switches or to have a separate tank as inverter, together with a separate transformer secondary winding, since the neutral point of this winding forms one terminal of the d.c. system.

Three main schemes had been suggested for use where reversible operation was required :—

(*1*) Two separate equipments, each consisting of tank and transformer winding, operated permanently in parallel, one as rectifier and one as inverter.

(*2*) A single tank and transformer winding, with d.c. reversing switches which are thrown over every time the direction of current flow reverses, the appropriate change of the grid control connections being made simultaneously.

(*3*) A normal forward-operating rectifier equipment in parallel with an equipment having reversing switches ; this latter equipment normally remains connected as inverter, but is thrown over to act as rectifier during times of heavy forward overload.

Scheme (*1*) gives completely smooth and instantaneous reversal, but its obvious disadvantage is the cost of the plant. Scheme (*2*) is cheaper, and is satisfactory in a few special cases ; but the total disconnection of the substation which occurs for an appreciable period during the moment of throwing over the reversing switches is an undesirable feature in railway service with heavy trains, as it is liable to give rise to broken couplings and to difficulties in the locomotives and in the control of the train. Scheme (*3*) is a compromise ; but its cost generally is not much lower than that of Scheme (*1*).

The South African Electricity Supply Commission solved the problem in this case by a fourth scheme, which combines to a considerable extent the advantages of the three arrangements just described. The feature of this is that the spare rectifier necessary for security of forward working

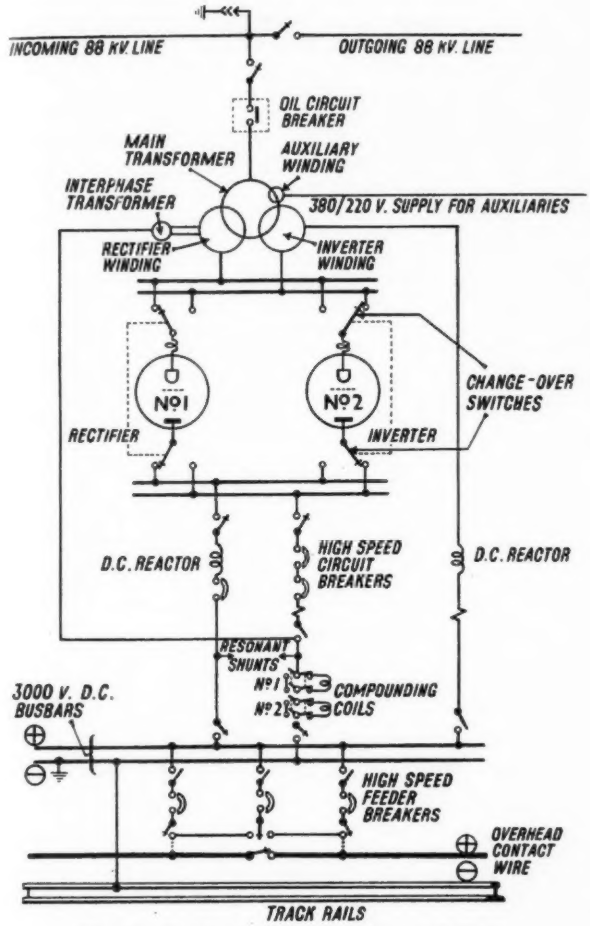


Fig. 2—Fundamental connections of B.T.-H. single-unit regenerative substation equipment

is used for the inverted working. Each substation (with a few exceptions) comprises a rectifier equipment and inverter equipment in parallel, similar to Scheme (*1*), but by means of off-load change-over switches the functions of the tanks themselves can be interchanged, or either tank shut down while the other remains in service. The fundamental connections are thus as shown in Fig. 2. It follows that in the event of trouble in one tank, whichever it is, the other tank can always be used as a spare for it to maintain normal forward operation for supplying the trains, and the regenerated current would then be handled by the inverters in adjacent substations. The fact which renders this permissible is that the currents regenerated by the trains are always substantially less than the forward currents and can therefore be transmitted greater distances to a substation.

As both tanks were to be equipped with full grid control apparatus, it was only a slight step further to arrange for the grid control to give a flat-compound characteristic. It was specified that the compounding apparatus should maintain the d.c. voltage constant within $\pm 2\frac{1}{2}$ per cent. of 3,000 volts, for constant a.c. supply voltage, from the maximum overload in the forward direction to the maximum overload in the inverted direction. It was also specified that the control grids should give arc suppression in the forward-operating tank in the event of backfire. Arc suppression cannot be applied in an inverter, for reasons which are given later.

It was specified that the equipments should be capable of operating satisfactorily on the load cycle shown in Fig. 3. By calculating the maximum r.m.s. loads over different periods of this load cycle the ratings of the B.T.-H. equipments were therefore fixed as follows :—

Forward :
1,667 kW continuous,
with overloads of 50 per cent. for two hours,
110 per cent. for 30 min.
200 per cent. for 1 min.
260 per cent. (6,000 kW) momentarily.

Inverted :
1,000 kW continuous,
with overloads of 25 per cent. for two hours,
100 per cent. for 30 min.,
175 per cent. for 1 min.
200 per cent. (3,000 kW) momentarily.

In addition the sets had to be suitable for operation in a tropical climate of high humidity, in ambient temperatures up to 40° C., at any altitude between sea-level and 5,500 ft., in conditions where dust and insects were prevalent, and in one of the worst lightning areas in the world.

Compounding and Inverted Working

Before describing the equipments it may be worth while to explain how compounding and inversion are effected, so as to show how these requirements affect the design. Fig. 4 shows the voltages from anode to neutral of a 6-phase rectifier, and the effects produced on the d.c. voltage when the firing of the anodes is delayed by various amounts, by control of the phase of the grid voltage. Diagram (*a*) shows the firing effected at an instant corresponding to normal uncontrolled rectifier working; diagrams (*b*) and (*c*) show the firing of the anodes delayed by increasing amounts, by delaying the instant, relative

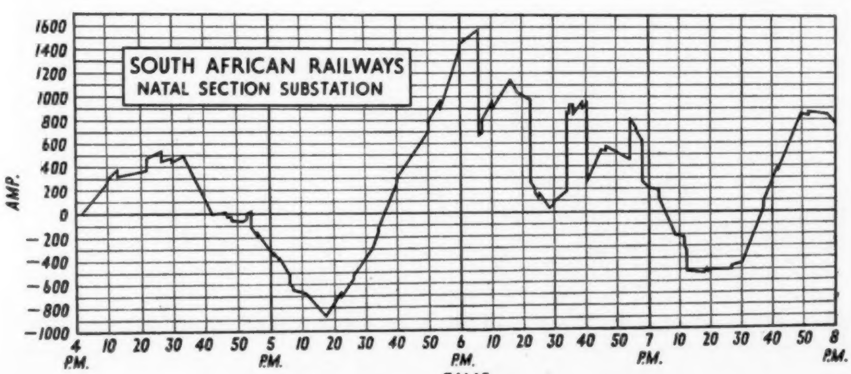


Fig. 3—Load cycle specified by the South African Electricity Commissioners for single-unit regenerative equipment

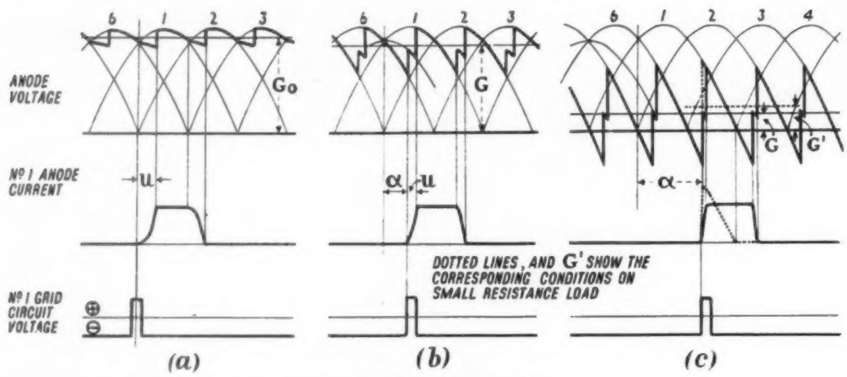


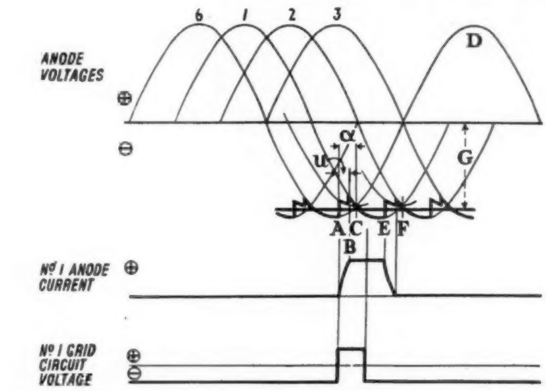
Fig. 4—Grid control of voltage of six-phase rectifier, with inductive d.c. load

to the anode voltage, at which the grid voltage changes from negative to positive. The current always tends to remain on whatever anode is firing until another anode of higher positive voltage receives a positive impulse on its grid. By progressively retarding the grid voltage the mean d.c. voltage can be smoothly reduced from a maximum down to zero, or by shifting the grid voltage in a suitable manner with change of load a compound characteristic may be obtained.

If, when the d.c. voltage has reached zero, the grid voltage is further retarded, it is still possible for current to flow if the current is " forced " through the rectifier by an external d.c. source against the opposing e.m.f. of the transformer windings ; *i.e.*, energy is then returned from the d.c. to the a.c. system. The conditions may then be as shown in Fig. 5, in which anode No. 1 is fired at point A ; commutation of the current from anode 6 to anode 1 takes place because anode 1 is more positive than anode 6 ; at point B the whole of the current has been transferred to anode 1. Similarly, at point E anode 2 is fired and commutation from 1 to 2 begins.

It can readily be shown that for either rectification or inversion the mean d.c. voltage G at light load is simply cos α times the theoretical maximum d.c. voltage Go, neglecting arc drop. That is, the d.c. voltage varies as a function of the firing angle α, as shown in Fig. 6. Simultaneously with the reduction of d.c. voltage the current in the a.c. system is displaced out of phase with the voltage by angle α ; that is, the power factor is lowered by the same amount as the d.c. voltage, as might be expected. Both for rectification and inversion the displacement of the current is in the direction that corresponds to reactive kVA

Fig. 5 (below)—Operation of six-phase inverter, returning power from the d.c. to the a.c. system



being drawn from the a.c. supply. Also, since the change of d.c. voltage with load is simply due to the resistance and reactance in the circuit, and these do not alter, it follows that the change of d.c. voltage for a given increment of load current is the same for any value of the firing angle α ; that is, the regulation characteristics are as shown in Fig. 7.

At this point it may be mentioned that the ideal regulation characteristics of rectifier and inverter as shown in Fig. 7 become modified at light load, due to the transformer connections employed and to the finite value of the inductance in the d.c. circuit, the result being as shown in Fig. 8*a*. Due to these effects and to the relative values of the voltages chosen for rectifying and inverting respectively, the result is that in a regenerative substation con-

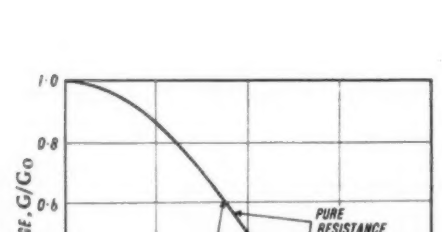


Fig. 6—Variation of d.c. voltage (at light load) as a function of the phase shift of grid voltage

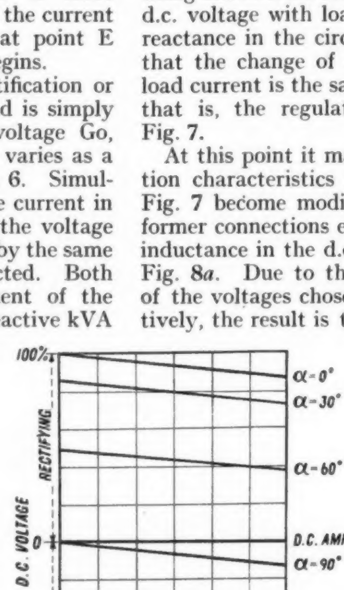


Fig. 7—Regulation characteristic of grid-controlled rectifier or inverter with highly-inductive d.c. circuit

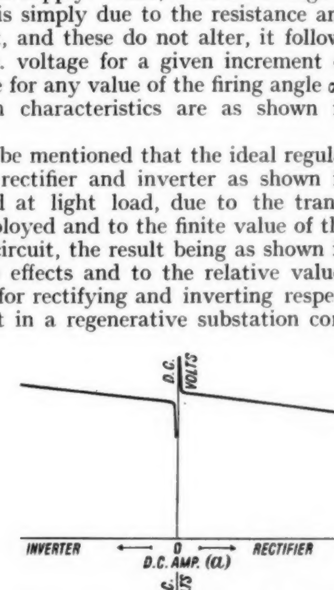


Fig. 8—Regulation of rectifier and inverter (a) separately and with no compounding, and (b) when in parallel with compounding

taining a rectifier and an inverter in parallel, a small circulating current is fed by the rectifier into the inverter at light loads. This circulating current has practically no effect on the overall efficiency, and is useful as it tends to keep the tanks from getting too cold during any long periods of light load. The overall regulation characteristic of the set comprising rectifier and inverter in parallel (both flat-compounded) thus becomes as Fig. 8*b*, *i.e.*, the transition from rectifying to inverting is smooth, due to the existence of this circulating current.

Next, from Figs. 6 and 7, the manner in which the grid voltage must be shifted with change of load in order to give a flat-compound characteristic in both directions is as indicated in Fig. 9. The special form of these characteristics, and the fact that the same phase-shifting apparatus had to be capable of giving either characteristic according to whether it was working for rectification or for inversion, governed the choice of the type of phase-shifting grid control apparatus employed.

Returning now to the inverted operation as shown in Fig. 5, it will be noticed that it is essential that the commutation of current from anode 6 to anode 1 should be completed while anode 1 is still substantially more positive than anode 6, otherwise the current will commutate back again. That is, the firing point A must be substantially ahead of the point of intersection C. This means that the grid control gear must be such that it cannot be retarded too far when working inverted. It is also essential that there should be no uncertainty about the firing, because if the current remains on anode 6 after point C a short-circuit will result, the a.c. and d.c. voltages at point D assisting one another in producing short-circuit current. This means that the requirements in the control grids are much more stringent than in rectifier working; not only must the grids hold back a greater anode voltage while the grid is negative, but when the grid becomes positive the anode must fire with certainty.

Further, the steady maintenance of the a.c. supply voltage is a necessity in inverter working. In rectification a momentary drop of the a.c. voltage produces merely a momentary reduction of d.c. voltage and current; but in inversion the a.c. voltage must be continuously available, to hold back the d.c. voltage and to transfer the current successively from anode to anode.

Rectifier Design

The rectifiers (Fig. 11) are of 6-anode construction, closely similar to that shown in Fig. 10 except that double control grids are employed. The ratings per anode are large. It is believed that even today the forward ratings still exceed by a considerable margin those of any other wide-range grid-controlled rectifier; and in the inverted direction they are more than double those of any other inverter. The combination of the large rating per anode with the grid-control conditions necessary for the tank to serve either as rectifier or as inverter created a problem of some difficulty as regards finding the best form of anodes and grids. Full discussion of this is beyond the scope of this article, but it may be mentioned that the experience

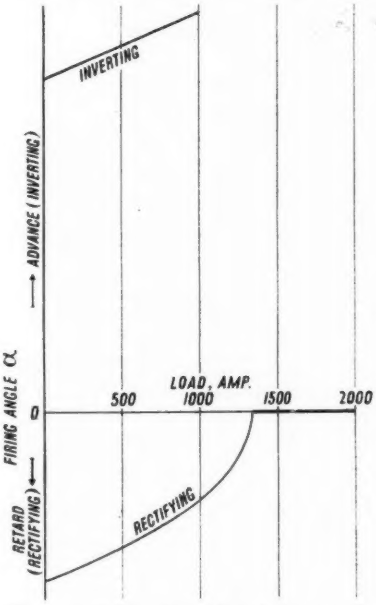
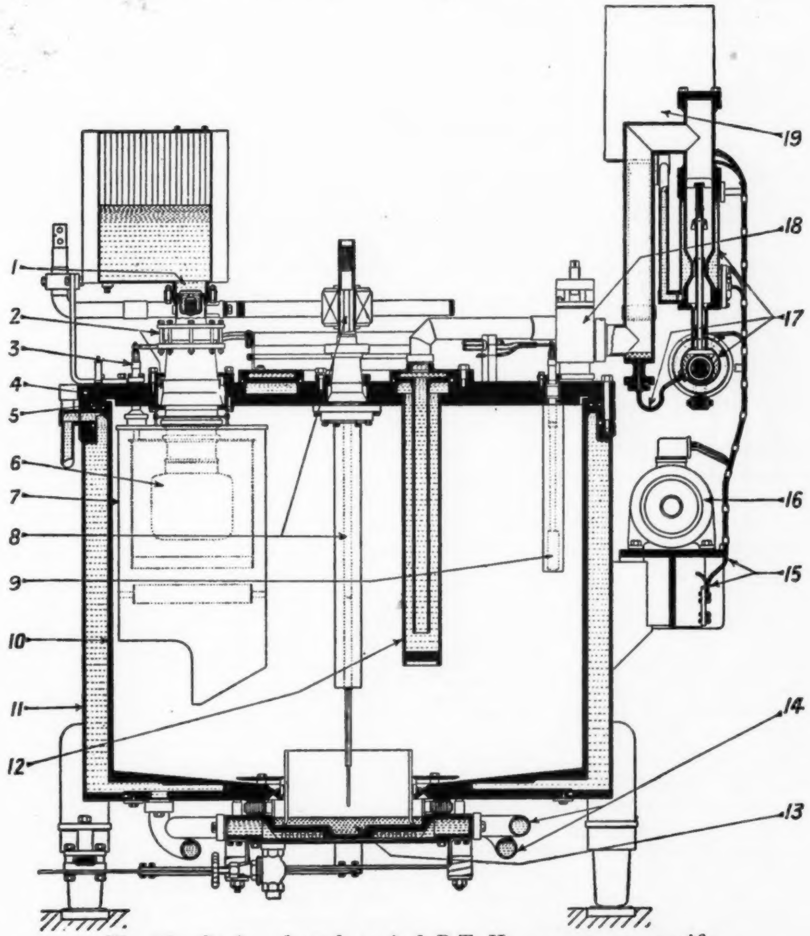


Fig. 9—Shift of grid voltage as a function of load



1—Anode cooler with thermostatic control
2—Anode seals
3—Control grid terminal
4—Anode plate
5—Main joint of vacuum chamber
6—Main anode
7—Anode shield with control grid inside
8—Ignition anode
9—Excitation anode (three-phase)
10—Vacuum chamber
11—Water jacket
12—Internal cooling tube
13—Cathode
14—Cathode water pipes
15—Auxiliary wiring
16—Motor driving vacuum pump, grid bias generator, and water pump
17—Mercury pump with automatic mercury levelling arrangement
18—Main vacuum valve
19—Pirani vacuum gauge

Fig. 10—Section through typical B.T.-H. mercury arc rectifier

gained subsequently gave valuable guidance in the design of normal uncontrolled rectifiers.

The grids have to hold back an anode voltage of about 8,500, and must also give complete certainty of firing. The double control grids, one above the other, are excited through separate resistances from the same source of grid voltage. This division, in effect, of the control grid into two halves permits a grid combination to be used which gives strong control, and a sort of step-by-step action is able to occur in the firing of the anode, which makes the firing definite in spite of the " stiff " design of grids. The use of three-phase excitation, which provides ionisation ready close to each of the six main anode shields, also gives obvious help to the grids in obtaining definite firing.

Other features which may be noticed in Figs. 10 and 11 include damping condensers on the grid circuits to suppress stray transient voltages (British Patents 242309 and 415546); thermostatic control of anode temperature (B.P. 464341); internal cooling tubes accessible from the outside (B.P. 401309); and automatic mercury levelling arrangement (B.P. 385376) to correct for mercury distilling over into or out of the mercury pump, as might otherwise readily occur with a closed circuit mercury pump cooling system in this high ambient temperature. Each rectifier is complete with its own closed circuit recoolers for main water and mercury pump water; a.c. ignition and excitation equipment; and vacuum pumps and gauges, all of normal design.

Grid Excitation

The grids are excited through resistances by a peaked a.c. voltage generated in a special peaking transformer. This is superimposed on a constant negative bias voltage

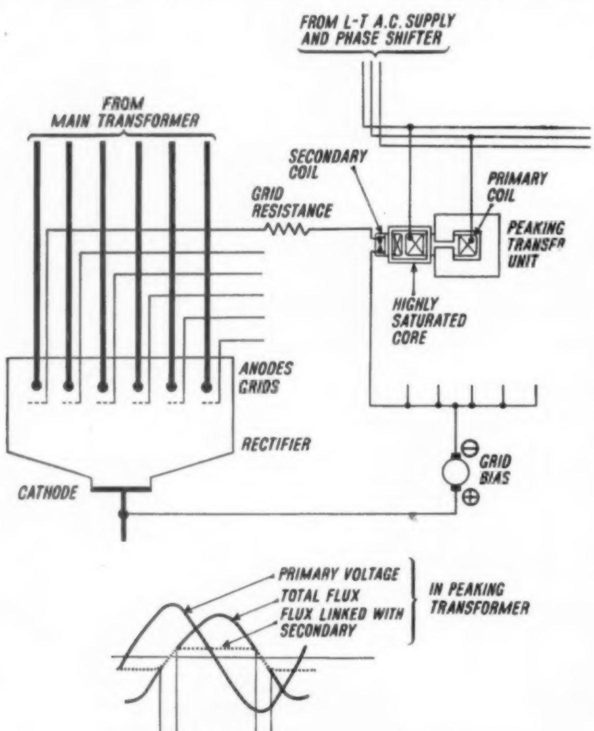


Fig. 12—Method of exciting grids, and principle of action of peaking transformer

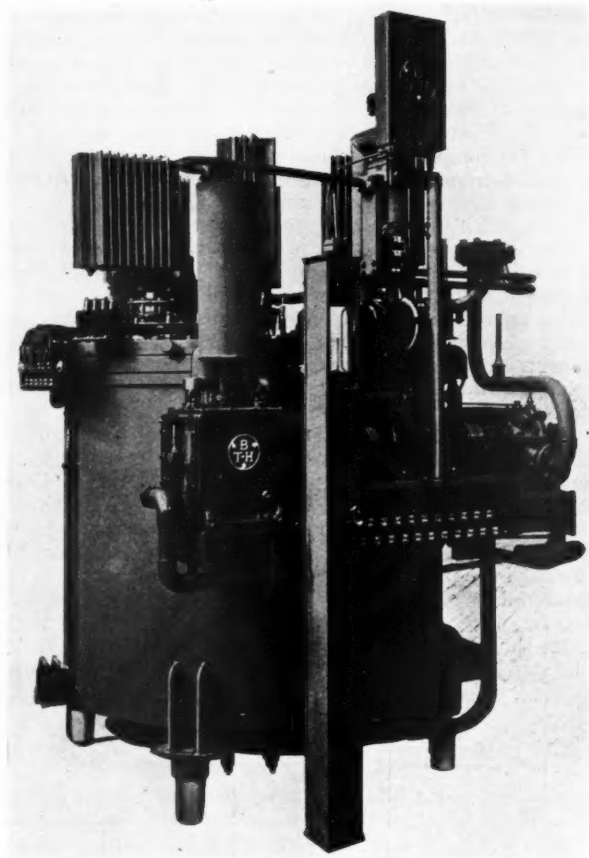


Fig. 11—B.T.-H. 3,000-volt rectifier rated 1,667 kW forward or 1,000 kW inverted

furnished by a d.c. generator driven by the vacuum pump motor and mounted on the rectifier. The principle of operation of the peaking transformer is shown in Fig. 12, from which it will be seen that the peaked secondary voltage is obtained due to the small core which carries the secondary winding being of insufficient section to carry the whole flux required by the applied primary voltage. The secondary peak occurs nearly at the point where the flux passes through zero; consequently the effect is almost independent of reasonable variations of the magnetic properties of the core, and hence there is no difficulty in obtaining permanence of characteristics and uniformity between one peaking transformer and another.

The choice of this type of apparatus in preference to the synchronous commutator method of exciting the grids was governed by two main considerations. First, it assists in giving the necessary certainty of firing, since the peaking transformer can be designed for any desired voltage and current output, and there are no limitations, such as those due to sparking, which might make it difficult to apply to the grids as much control power as is required. The second requirement is associated with the possibility of hunting and load swinging. When it is considered that a shift of 3 deg. in the grid voltage of the inverter may be enough to change its load from no load to full load, and that the sets work at the end of a transmission line up to 186 miles long, in which changes of load produce changes of phase of the high-tension voltage, it is evident that a static form of grid control apparatus, giving instant

response to phase swinging, is most desirable. If there were a delay in the response of the grid control apparatus to a shift of a.c. voltage this might result in a large change of load current, which in turn might produce a further shift of a.c. supply voltage, so that under some conditions hunting could build up. The peaking transformer method of exciting the grids has the advantage that it does not itself contain anything which can hunt; and in addition, due to its instantaneous response, it not only prevents the main load current of the rectifier or inverter from co-operating in building up hunting but causes them to act as damping on the system, thus reducing the tendency of the system as a whole to hunt due to other causes.

The peaking transformer also gives the necessary insulation from the grid circuits to the low-tension supply circuits; and with the oil-immersed construction it has been easy to provide insulation having a large margin of safety. For the same reason the various resistances in the grid circuits are mounted on panels at the top of the peaking transformer, with generous insulation between circuits and with porcelain insulation to ground; and the high-speed relay for arc suppression is also mounted on these panels (see Fig. 13).

Phase-Shifting Apparatus

The choice of method of shifting the phase of the grid voltage with load was governed by the rather peculiar form of the characteristics shown in Fig. 9. The power factor of the railway load as a whole depends mainly on the power factor obtained at medium and heavy loads when rectifying; and to keep this power factor reasonably

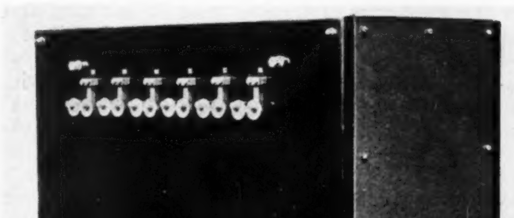


Fig. 13—B.T.-H. peaking transformer, with grid resistance panels and arc suppression relay

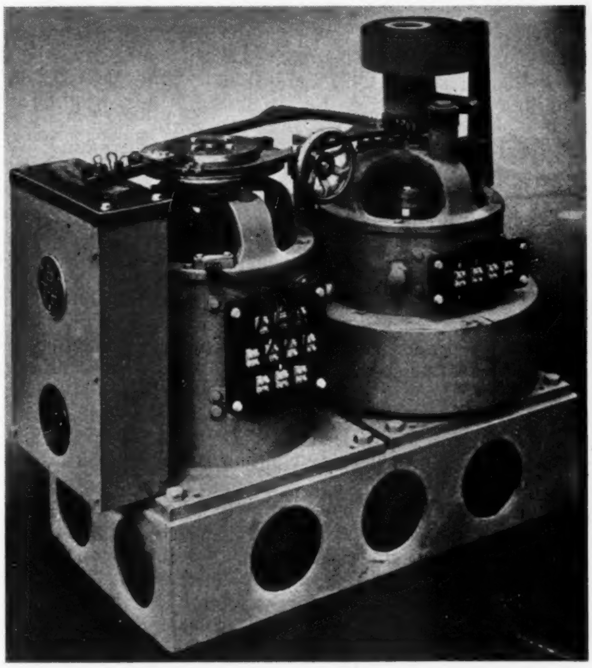


Fig. 14—B.T.-H. phase shifter and torque motor

high necessitated a fairly close approximation to the theoretical characteristic, in which the rate of shift becomes greater and greater as the forward load is increased. Simple electrical methods of phase-shifting, which are at first sight attractive, mostly give the reverse of this characteristic, *i.e.*, a rate of phase shift that becomes slower and slower as the load is increased; that is, they give a humped form of regulation characteristic, which prevents compounding up to such high values of overload if the d.c. voltage is to be held within the specified limits of $\pm 2\frac{1}{2}$ per cent.

For these reasons a purely mechanical method of phase shifting was adopted. This apparatus, see Fig. 14, consists of an induction regulator type of phase shifter in the primary supply to the peaking transformer, rotated as a function of load by a d.c. torque motor acting against a spring. The torque motor, the design of which is similar to that of the torque motors used for synchronous motor field control in the earlier motor-generator substations, has its armature supplied from a constant-voltage d.c. source, and its main field winding carries the main load current; there is also an oil dashpot at the bottom which gives approximately critical damping.

The requisite curved characteristic when rectifying is produced by causing the motion of the phase shifter to cut out a resistance in the torque-motor armature circuit as the phase shifter is advanced, by means of the rheostat seen at the left in Fig. 14. When the connections are changed over from rectifying to inverting this continuously varying rheostat is replaced by an adjustable fixed rheostat, so as to give the changed and substantially constant rate of movement with load that is then required; and at the same time the armature current is reversed so that the direction of movement with load is still correct.

The torque motor arm engages with a stop to prevent retarding too far under any conditions when inverting, and also to prevent advancing too far at extreme overloads when rectifying. The change of phase of grid voltage relative to anode voltage, as between rectifying and inverting, is given partly by appropriate connections in the

main anode changeover switchgear; partly by changing the terminals to which connection is made on the phase-shifter stator; and partly by an initial phase shift when rectifying, produced by an additional shunt-excited field winding on the torque motor. This shunt field winding is excited only when connected for rectifying.

By varying the current in this shunt field winding, by the rheostat provided, the d.c. voltage can be raised or lowered just as by the field rheostat on a d.c. generator; and the circulating current between rectifier and inverter can be similarly controlled. The torque motor and phase shifter are at low voltage, and hence any desired adjustments can be made while the plant is alive.

Stability

The question of stability of parallel operation of the compound rectifier and inverter also required consideration. It will be seen that with characteristics such as are shown in Fig. 8*b*, if the compounding apparatus is simply connected in series with the cathodes of the individual tanks the conditions are, or can easily become, unstable; *i.e.*, an increase of circulating current due to any cause will raise the voltage of the rectifier and depress that of the inverter, thus tending to produce a further increase of circulating current, and so on. In fact, with that connection stability can only be obtained by working very nearly in "shunt." The difficulty was overcome on these equipments by arranging the connections so that the circulating current does not pass through the compounding apparatus, but only the total output current of the substation. This connection, shown in Fig. 2, is equivalent to the equaliser connection commonly used in parallel operation of compound rotating machines, but is more effective due to the load current passing through the compounding equipments in series. With this arrangement perfect stability of circulating current is, of course, obtained with level compounding in both directions, or even with over-compounding.

As the total output current of the station passes through both torque motors, by-pass isolating switches of the make-before-break type are provided in the main series connections to the torque motors, so that any torque motor can be taken completely out of service if required without interrupting the supply from the substation.

It is of interest to consider what is the effect of current passing through the torque motor in the opposite sense to that required for compounding. An increase of forward current supplied by the substation causes the rectifier torque motor to advance the phase of its grid voltages (as is required for compounding), and at the same time causes the inverter torque motor to move in the opposite direction; this slightly raises the d.c. voltage of the inverter, thus keeping the circulating current small; but excessive retardation of the inverter grid voltage, which would lead to short-circuit, is prevented by its torque-motor arm engaging with the stop as shown in Fig. 14. In the case of an increase of regenerated current fed to the substation, the inverter grid voltages are advanced (as required for compounding), and the rectifier grid voltages are retarded; but in this case the rectifier torque motor goes on retarding past its no-load setting, *i.e.*, to the point where its series and shunt fields neutralise each other, before the stop is reached. This gives a valuable increased margin of stability of the circulating current when regenerated current is flowing. Due to these features and to the value of damping provided, the circulating current is maintained correct both during rapid changes of load and under all steady-state conditions.

Transformers

The disadvantages of taking a separate small supply from a large high-voltage system, especially in a lightning district, are well known. Consequently it was decided to supply the rectifier auxiliaries and various other small loads in and near the substations, from an auxiliary winding on the main transformer. This was permissible due to the existence of the anode change-over switches, which enable the rectifier or inverter to be disconnected without shutting down the main transformer. The design of the main transformers (see Fig. 15) thus became unusually interesting. Not only were there four separate windings to be provided, but the location of the windings with respect to one another in the transformer had to be carefully studied in order to obtain suitable values of reactance from each winding to each of the others; the primary winding had to be specially insulated for the severe lightning conditions; and the complete transformer had to pass a rather small loading gauge.

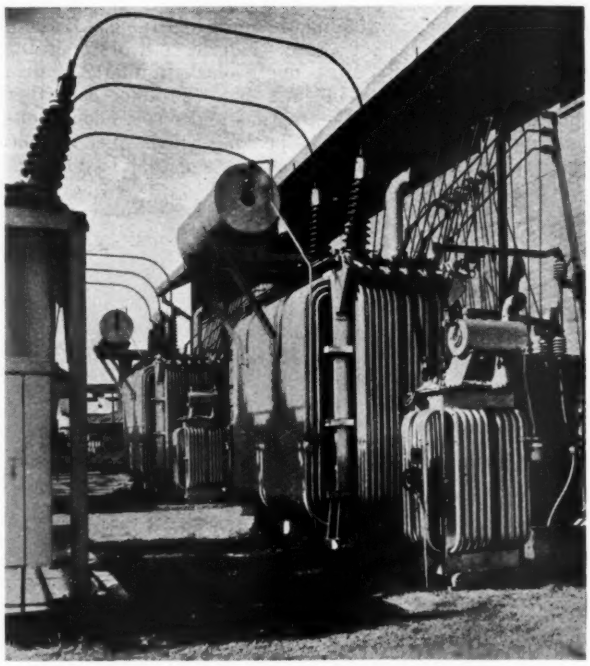


Fig. 15—Main and interphase transformers at Booth substation

From what has gone before it will be realised that a fairly low voltage of inverter winding is necessary to obtain maximum power factor on inverted loads; whereas for maximum reliability of inversion this voltage should be high relative to the d.c. voltage. In the case of these equipments the power factor of the inverted load is unimportant, since, although large inverted loads are met with at the individual substations, the total inverted load on the system at any given time is negligible compared with the forward loads; on the other hand the great length of the a.c. transmission line and the heavy inverted peak loads expected made it necessary to do everything possible to make the inverter as stable and reliable as possible. The voltage of the inverter winding was therefore made high, 3,700 volts from anode to neutral, corresponding to a rating of the inverter winding of 3,000 kVA, the connection being 6-phase triple-star.

The rectifier winding is connected 6-phase double-star, with a voltage to neutral of 2,930 and a rating of 2,820 kVA; the interphase transformer for this is mounted in a separate tank (see Fig. 15). The auxiliary winding on the main transformer is rated 100 kVA, 380/220 volts, with the neutral brought out. The primary winding, allowing for the combined loads on the other windings in accordance with the load chart, is rated 2,500 kVA and is star-connected

for 88,000 volts, 50 cycles, with full-capacity off-load tappings of + 3 per cent., 0, — 3 per cent., — 6 per cent. and — 9 per cent.

Control and Auxiliary Circuits

In the design of the auxiliary circuits the governing consideration was to reduce as much as possible the number of points where breakdown could take place from apparatus at 3,000 volts d.c. potential to earth, since many of the auxiliaries of the tank acting as rectifier must operate at this potential.

With this object all small insulating transformers between these high-voltage circuits and earth potential circuits were eliminated, leaving only three insulating transformers, viz. : the peaking transformers for the grids, the ignition and excitation transformers, and one main insulating transformer ; these three transformers are large enough to have ample insulation and they are of oil-immersed construction. The connections are thus as shown in Fig. 16. In addition, all auxiliary circuits at 3,000 volts potential are segregated by mounting them on separate panels on porcelain insulators, and the control interlocks between the h.t. and l.t. circuits are given by insulating links. These high tension control panels are subdivided into four sections for each tank, viz. : one for the grid control circuits and arc suppression (Fig. 13), one for the ignition and excitation (Fig. 17), one for the Pirani gauge, and one for the general h.t. control gear.

All high-tension auxiliaries associated with each tank are located adjacent to that tank in a locked enclosure. As a further precaution against breakdown to earth, the high-tension auxiliary wiring between the various high-voltage auxiliary panels and from them to the rectifier is carried direct across in conduit pipes, so that its insulation is not subject to the potential difference to earth. Grid control, ignition and excitation, and general auxiliary circuits are kept separate from one another.

The general control scheme is that the stations are unattended, the plant being equipped with all necessary protective features and alarms being sounded in the neighbouring attendants' quarters in the event of a shutdown due to any cause. Starting up, reclosure of circuit breakers, and interchanging the functions of the two tanks when required are done manually.

The anode and cathode change-over switches (Fig. 18, on left) for interchanging the functions of the tanks, are gang-operated and interlocked so that two tanks cannot be paralleled on the same transformer winding. The corresponding change-over of the control circuits, all of which are at low tension, is done by the drum controller seen in the centre of the common l.t. control panel (Fig. 19). Castell key interlocks ensure that the control change-

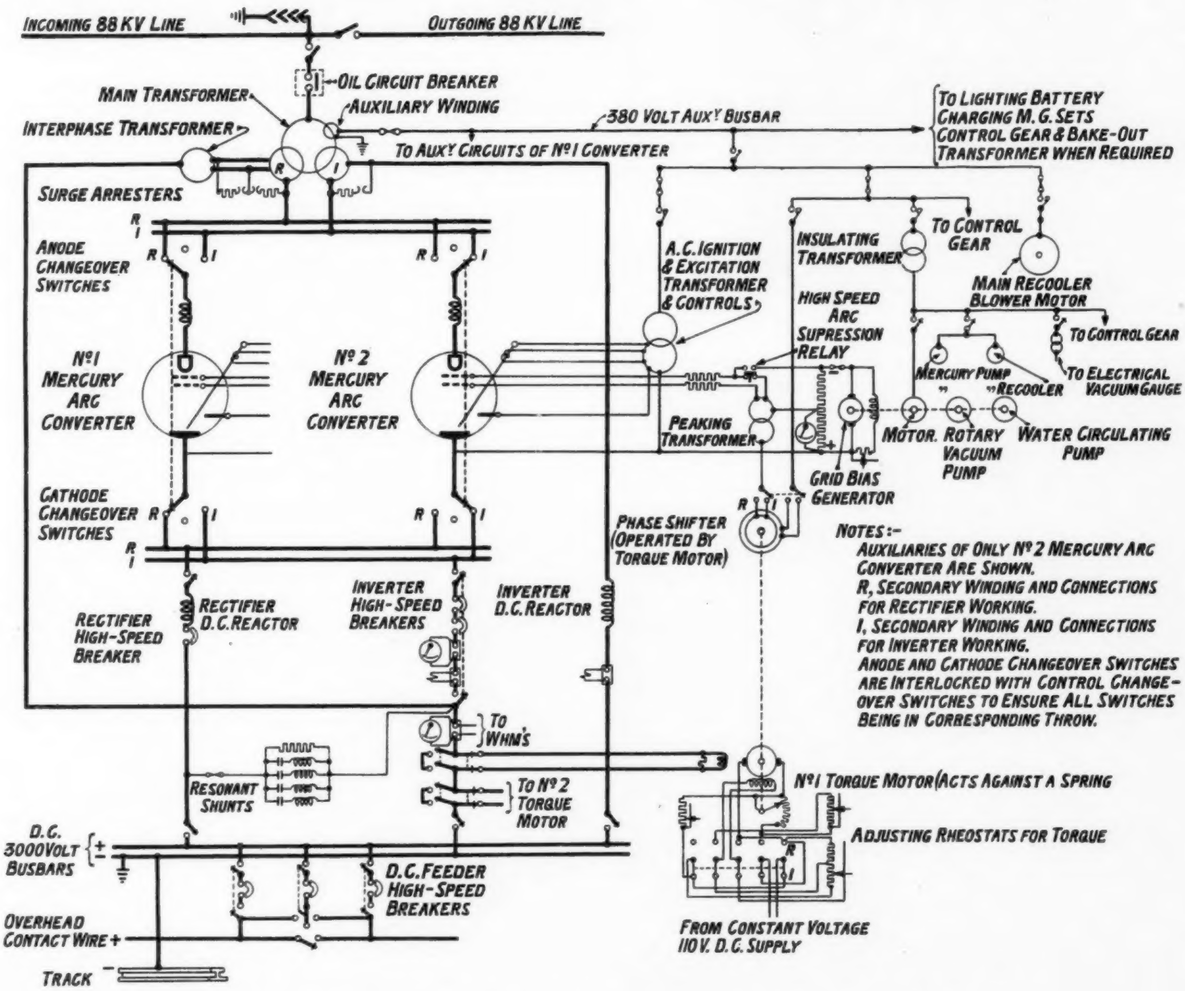
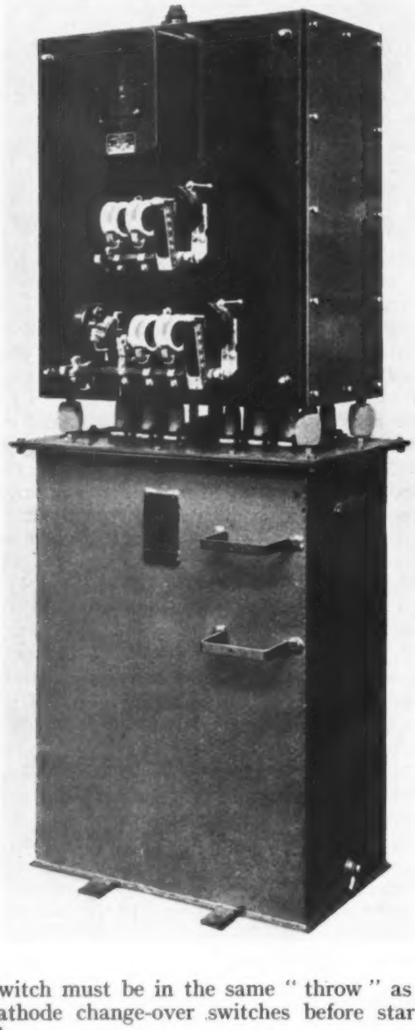


Fig. 16—Single-line diagram of main connections at inverted rectifier substation



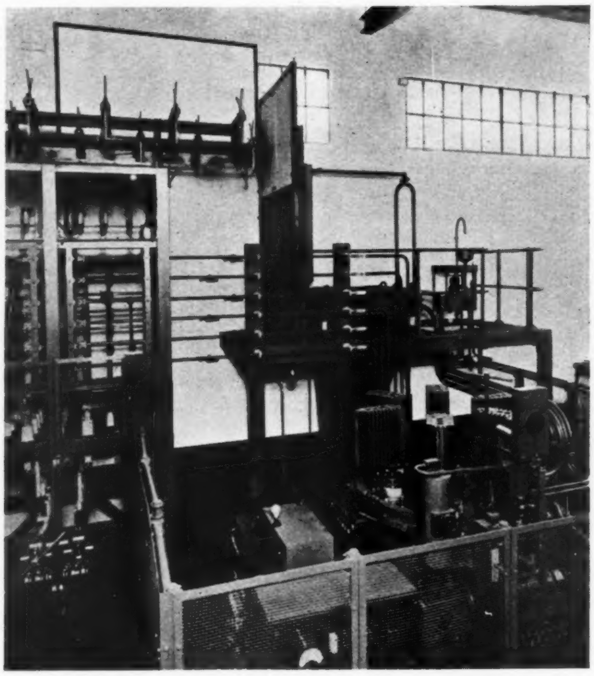


Fig. 18 (above)—Portion of Mariannhill substation on the Cato Ridge-Durban section, showing on the left the anode and cathode change-over switch cubicle

Fig. 17 (left)—Ignition and excitation transformer, and control panel, as installed in the B.T.-H. substations on the South African Railways

over switch must be in the same " throw " as the anode and cathode change-over switches before starting up is possible.

A main substation battery is provided for operating the various circuit breakers and for general control purposes; and two small motor-generator sets supplied off the 380-volt a.c. auxiliary circuit are available for battery charging and for giving the constant-voltage d.c. supply for the armature and shunt field of the torque motors.

A portable bake-out transformer is also provided which can be used to bake out any tank on the system; this transformer is supplied off the 380-volt auxiliary circuits. The bake-out current is controlled by a small portable loading resistance at small values of current, while at larger values of bake-out current this loading resistance is cut out and grid control is employed, using the handwheel which can be seen in Fig. 14 at the top of the phase-shifter. The anode and cathode change-over switches and associated control gear permit either tank to be baked out in safety while the other tank is on load.

D.C. Switchgear

The general arrangement of d.c. switchgear can be seen in Fig. 20. The 3,000-volt high-speed circuit-breakers are mounted in cubicles on a gallery, with the d.c. busbars and isolators beneath. The isolators are remote-mechanically-operated, and Castell key interlocks ensure that it is not possible to enter a high-speed breaker compartment until the breaker has been isolated on both sides. There are also Castell key interlocks to prevent opening any isolator or change-over switch on load. A similar system of Castell key interlocks ensures that the rectifier enclosure cannot be entered until it has been made completely dead.

Non-Standard Substations

In three substations departures from the standard arrangement so far described have been made. At Dannhauser and Newcastle the anticipated inverted loads were small enough to be dealt with in the adjacent substations, and the inverters were accordingly omitted; also these two substations are arranged for fully automatic control. Otherwise they are similar to the standard regenerative substations. At Booth substation, at the Durban end of the line, the anticipated forward loads were too great for a single rectifier, and this substation is accordingly constructed as a double-unit regenerative substation, *i.e.*, it contains two sets each consisting of rectifier, inverter, common transformer and associated apparatus. As the inverted loads are small, only one of the two available inverters is used, the other remaining disconnected by means of the anode and cathode change-over switches.

This arrangement at Booth created a special problem in regard to the compounding apparatus, since it was desirable to adhere to the connection of the torque-motor main fields in series with the total output of the station. With such a connection, however, the series field windings would not be suitable for carrying the combined currents of two rectifiers, nor would they give the correct compound

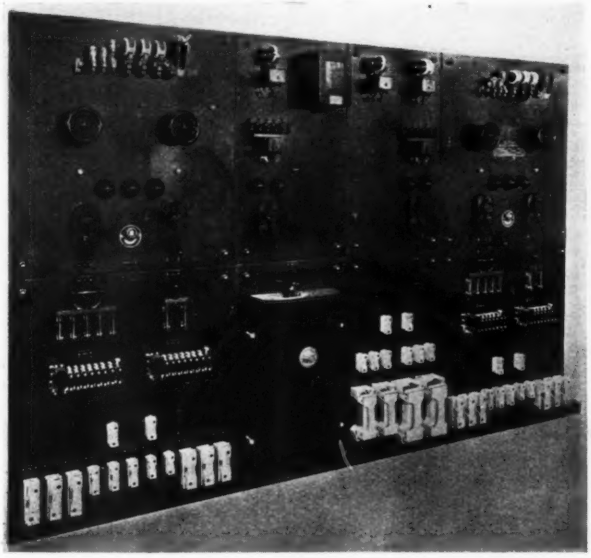


Fig. 19—Low-tension control panel for mercury arc rectifier and inverter

characteristic even if they did so ; further, it was necessary that the equipments should work correctly if only one rectifier were in service instead of two. The compounding arrangement therefore adopted in the case of Booth is shown in Fig. 21. The torque motors remain in series with the total output of the station, but are shunted by a resistance equal to the combined resistance of three torque motors plus their connections. The contactor in the diverter circuit opens under the control of the reverse power relay when inverted current is flowing, and it is also opened if only one rectifier is working. Consequently the flat compound characteristic in both directions is correctly given irrespective of the number of rectifiers in service, and the circulating current is still completely stable. A failure of the diverter contactor would merely result in the characteristic being partially shunt instead of being a flat-compound characteristic.

Tests

For the purpose of the official test a complete regenerative substation equipment, consisting of rectifier and inverter with all their auxiliaries, main transformer, and additional transformer to step up to 88,000 volts, was erected in the B.T.-H. works at Rugby, and tested in conjunction with the 3,000-volt motor-generator equipments used for normal rectifier tests. The tests, which included operation on the specified load cycle of Fig. 3, operation on the guaranteed loads and overloads, and repeated rapid load swings from 4,500 kW forward to 2,000 kW inverted, were passed with entire success. The overall efficiency was measured and exceeded 96 per cent. at full load rectifying or 94 per cent. at full load inverting with both tanks working and normal circulating current flowing. The total loss under the same conditions at no-load was below 25 kW.

Compared with the equivalent motor-generator equipments the losses are therefore of the order of one-third or less. The full load power factor exceeds 0·91 when rectifying or 0·58 when inverting. The reasons for choosing a low power factor for inversion have already been given. The tests showed improvement on the guaranteed performance figures in all respects.

General Service Performance

The Durban-Cato Ridge section was opened to full commercial service on December 1, 1936, and the Glencoe-Volksrust section in October, 1937. Since those dates very heavy traffic has been carried, approaching the designed maximum tonnage for the whole of this electrified section. Sufficient experience has thus been gained to enable general conclusions to be drawn regarding this class of converting plant under severe conditions.

Tests were performed at the outset consisting of the simultaneous operation of two 1,000-ton trains on a 1 in 70 grade, both upwards and downwards, with a single rectifier and inverter to supply them, and these tests were passed in a satisfactory manner. The compounding apparatus was also tested and found to operate correctly

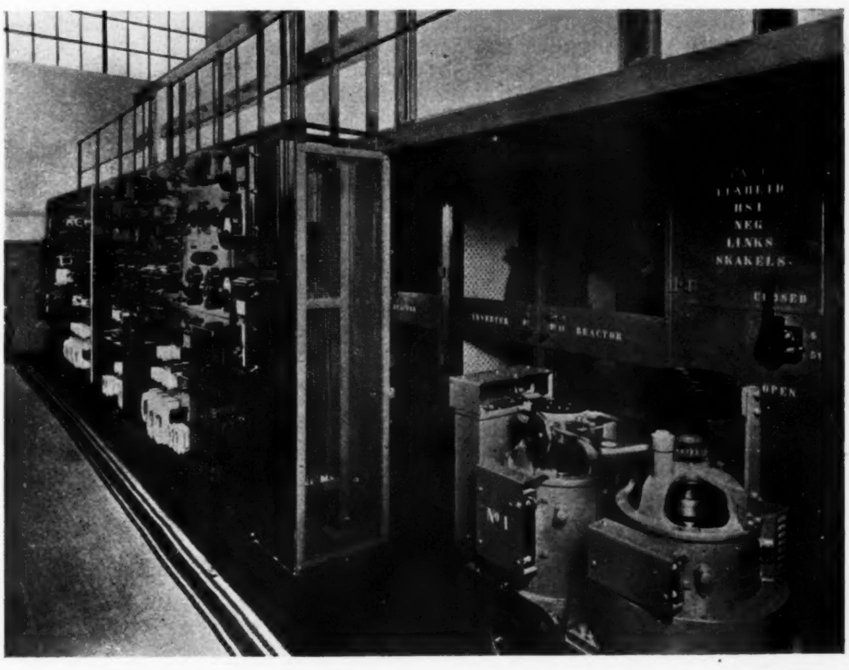


Fig. 20—3,000-volt d.c. switchgear and low-tension control gear at Mariannhill substation, South African Railways

in both directions; and parallel operation of the flat-compound rectifier and inverter was found to be completely stable.

Remarkable loads have been carried at times. Operating as a rectifier, a single tank has successfully carried practically three times full load for over 10 min. and inverted loads of over 3,000 kW on a single unit have been carried without difficulty. Transition from rectifying to inverting or *vice versa* is perfectly smooth and steady, and it is noteworthy that the locomotive drivers have come to have complete confidence in these inverters, and normally control the trains on down grades in these sections by regenerative braking alone.

The method of exciting the grids by static apparatus has proved its value, as both rectifier and inverter have been found to operate steadily without sudden swings of current or hunting. Actually the equipments have been tried experimentally on an already hunting a.c. system, and found to work steadily. The speed of response of the torque motors to variations of substation load current has proved to be ample. The automatic levelling arrangement on the mercury pumps has also been successful. With cooling air temperatures up to the maximum of 40° C. normally permitted for these equipments, no mercury pump has had to have its mercury level attended to in over three years of service.

Perhaps the most important point that had to be determined by service experience was the degree of reliability obtainable with inverter equipments at the end of a long transmission line with large overloads and large voltage surges. Experience has shown that these conditions affect the inverters considerably less than might have been anticipated, and actually the interruptions on the inverters have been negligibly few and not greater than on the rectifiers.

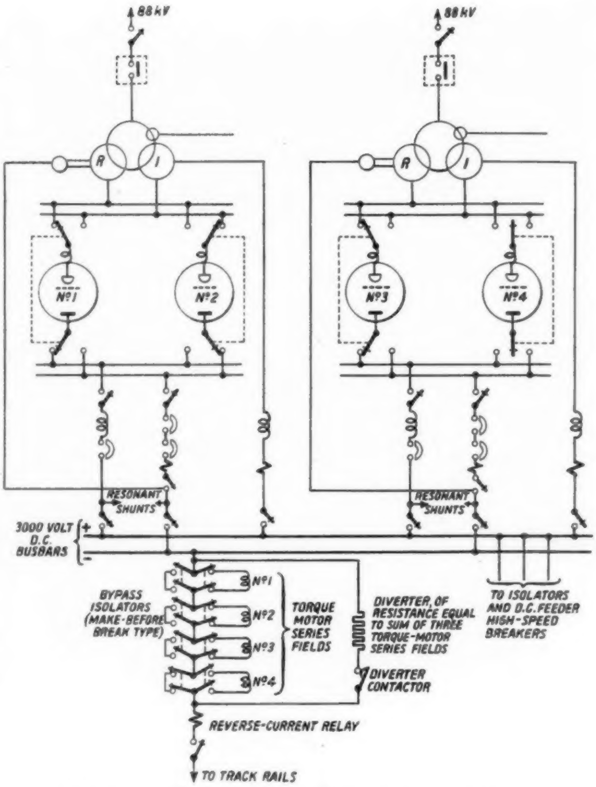


Fig. 21—Diagram of fundamental connections at Booth (double-unit regenerative) substation

Lightning Interruptions

The severe lightning conditions in the district have proved the principal source of interruptions. As regards lightning surges coming in from the d.c. side, flashover, with resultant damage, has occurred in a few instances to the outgoing d.c. feeder equipments, and short lengths of cable, of 40 to 120 yd., are inserted in the d.c. feeders in most of the substations to reduce the severity of the lightning stresses on the feeder equipments. With this exception there have not been any actual plant breakdowns due to lightning, and the thorough insulation to earth of the main and auxiliary 3,000-volt circuits has thus proved beneficial.

As regards the a.c. side, lightning surges from the 88-kV lines pass through the transformers and appear on the secondary windings, across the anodes of the rectifiers and inverters. That the high voltages on the secondary windings are due to this cause has been demonstrated by operating the transformers with the rectifiers and inverters disconnected. Voltages of between 20 and 30 kV thus become impressed on the anodes; and while the insulation is sufficient and no breakdowns have occurred, nevertheless the condition is severe and results in occasional interruptions on the rectifiers and inverters. The tanks have shown themselves to be somewhat more sensitive to these surge voltages when acting as rectifiers than when acting as inverters. A study has been made of methods by which these over-voltages on the anodes could be reduced, but it has not so far been considered necessary to modify the equipments for this purpose, as the interruptions are by no means frequent and are less frequent than the interruptions caused by ordinary track faults such as occur in all railway service.

Resonance Effects

Another complication met with is resonance on the 88-kV transmission lines. The length of transmission line from Colenso to Booth is 186 miles, which makes it exactly a ¼-wave length line for the 5th harmonic. In consequence, strong resonance with the 5th harmonic builds up under certain conditions of load. In the opposite direction, from Colenso to Volksrust, the distance is not much less, and resonance again occurs under suitable load conditions. The case is a particularly difficult one because the load on this a.c. system is almost exclusively railway load, *i.e.*,

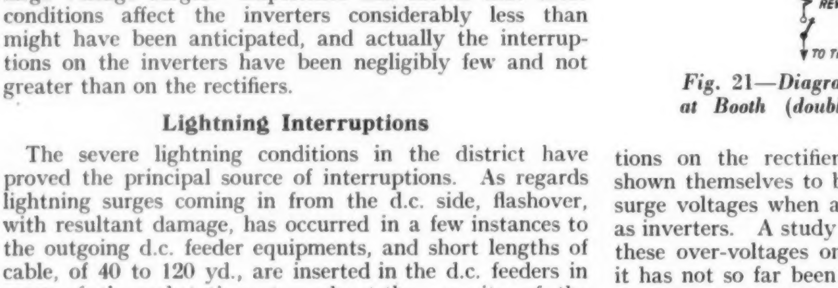
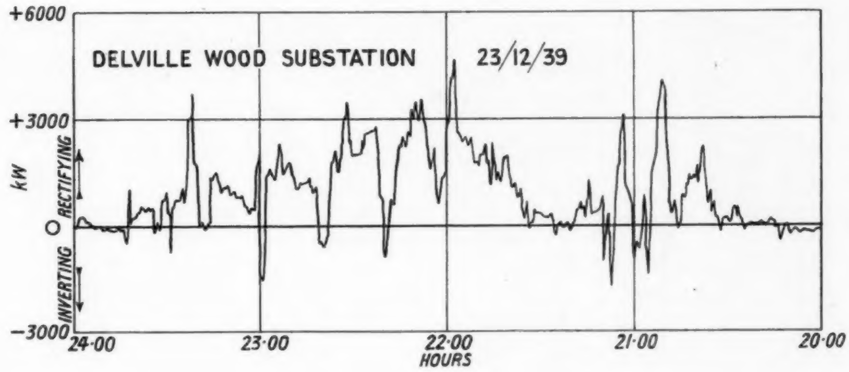


Fig. 22—Daily load chart for Hammarsdale substation on the Cato Ridge—Durban line

Fig. 23—Daily load chart for Delville Wood substation, Cato Ridge — Durban section, South African Railways



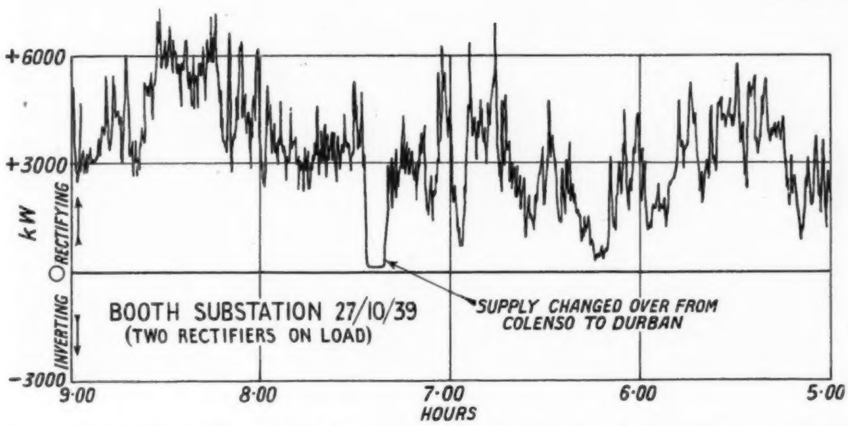


Fig. 24—Daily load chart for the double-unit rectifier substation at Booth, near Durban

the damping effect of general load on the a.c. system at times goes down to a very low value.

The resonance affects the operation of the substation equipments in two ways. In the first place it produces a very slight shift of the grid voltage, which tends to reduce the circulating current between rectifier and inverter to a point where (due to the finite value of the smoothing inductance) the circulating current becomes discontinuous. Secondly, the resonance produces large over-voltages on the transformer secondary windings and anodes, which at times reach very high values, and which are of importance because they may persist for considerable periods. These over-voltages have been proved to contribute to the occasional interruptions previously mentioned; and they also constitute a further difficult condition for the anode surge arrestors. On about five or six occasions the over-voltages due to resonance have persisted so long that the resultant sustained arcing at the horns of the surge arrestors has only been interrupted by shutting down the equipments, either manually or by operation of the protective devices. It may be mentioned that sustained voltages above normal but below the spark-over value of the horn gap are cleared by the arrestors without difficulty.

Methods of reducing these resonance over-voltages have been considered, but so far the occasions when these have persisted long enough to produce damage on the arrestors have been few enough not to be of serious consequence. The fireproof construction of the arrestors has no doubt

TABLE I.—Substation Loadings, Cato Ridge to Durban Section, 1939

	Booth		Mariannhill		Delville Wood		Hammarsdale		Cato Ridge	
	Forward	Regen.	Forward	Regen.	Forward	Regen.	Forward	Regen.	Forward	Regen.
January	1,368 520	4,456	433,260	26,730	478,609	52,737	236,481	50,530	269,811	36,402
February	1,316,889	3,881	368,862	28,750	454,590	46,490	201,700	48,253	347,630	30,799
March	1,485,285	4,665	416,373	33,957	383,851	74,656	276,467	38,254	274,094	43,887
April	1,475,711	4,990	344,733	45,005	426,675	58,519	264,953	46,847	297,216	38,630
May	1,511,617	6,088	305,515	52,777	476,872	63,261	216,150	52,638	350,870	32,106
June	1,590,174	3,297	323,160	46,916	459,419	47,540	254,783	51,589	291,870	37,076
July	1,671,893	3,336	384,709	44,154	579,922	43,639	265,327	50,935	246,162	40,382
August	1,629,635	3,841	344,915	51,084	586,154	45,787	254,136	42,520	224,644	58,865
September	1,620,909	3,198	404,636	32,729	554,359	53,529	293,233	43,441	224,856	67,904
October	1,651,522	5,841	453,177	27,571	559,015	52,450	312,242	37,244	352,561	29,710
November	1,762,703	723	485,396	33,581	420,867	85,635	367,428	34,779	419,938	40,768
December	1,665,793	2,188	381,065	44,491	546,107	82,368	327,755	49,688	347,460	42,392
	18,750,651	46,504	4,645,801	467,745	5,926,440	706,611	3,270,655	546,718	3,646,264	498,921
Load factor	64·2%	0·53%	31·8%	5·35%	40·6%	8·07%	22·4%	6·24%	25·0%	5·70%
Ratio $\frac{\text{Regen.}}{\text{Forward}}$	0·25%		10·1%		11·9%		16·7%		13·7%	

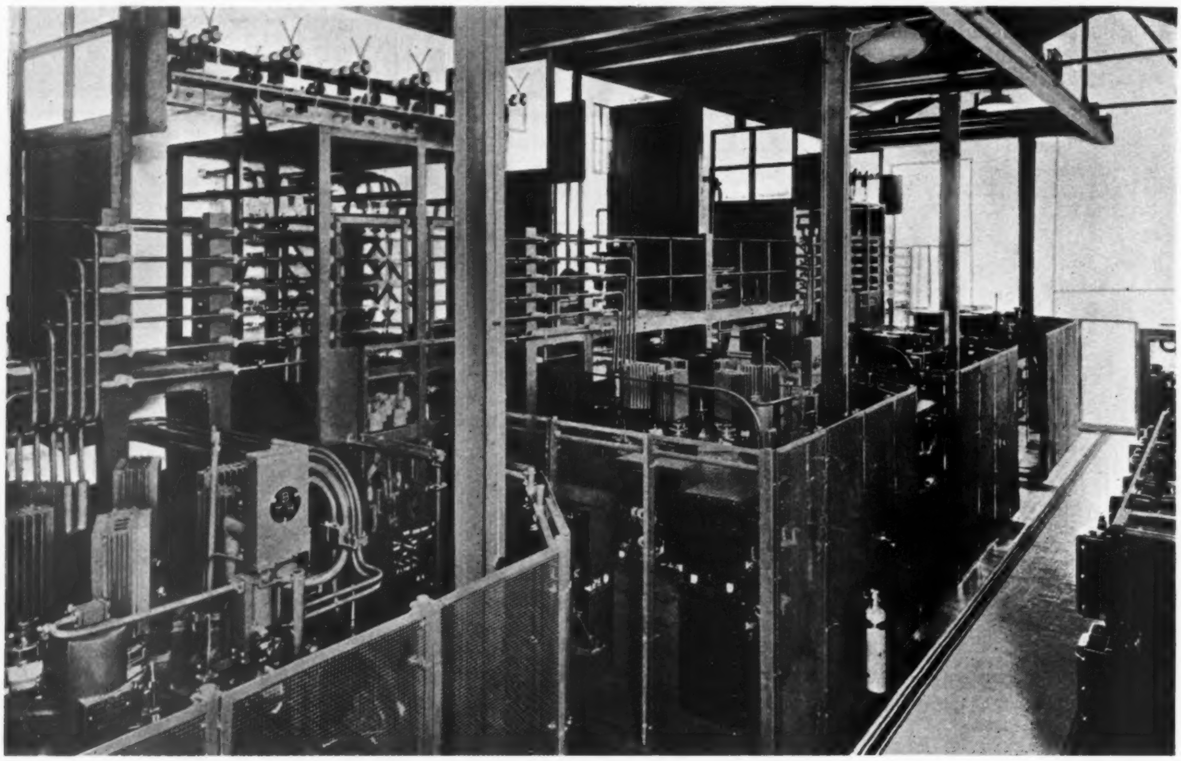


Fig. 25—Interior of Booth double-unit regenerative substation at the Durban end of the Natal main line

contributed to enabling them to deal with the majority of cases of sustained over-voltage, which last only for relatively brief periods. It is worth noticing that the peaking transformers have proved themselves so insensitive to these large distortions of a.c. voltage wave-form that the only effect produced is the slight alteration of circulating current.

Experience also has shown that it was necessary to make a number of minor alterations in the automatic control gear to prevent interruptions which previously occurred due to control contactors dropping out as a result of momentary dips in the a.c. voltage. The contactors in question were of normal construction and drop-out voltage, and it is noteworthy that the inverters have actually been found less sensitive to such fluctuations of a.c. voltage than the contactors themselves.

Substation Loadings

Typical load charts in service are illustrated in Figs. 22 to 24; and Table I gives particulars of the substation loadings of the Cato Ridge to Durban section for the year 1939. The figures in Table I include a certain amount of current interchange between substations, but the correction to be allowed for this is probably small. Current circulating within the individual substation is not included in the figures. The loads carried by the inverters during short periods are, of course, very much higher than might be indicated by the load factors.

In the forward direction the load factors reach figures which are high for main-line service when it is considered that these load factors are merely the averages over a long period, including nights and weekends, and that the figures do not include the internal circulating current between rectifier and inverter in the same substation. In fact, the load factor for Booth substation, which reached 73·5 per cent. average over the month of November, 1939, is such as is seldom met with in railway practice.

It is interesting to consider how far the provision of the inverter equipments is justified by the inverted loads carried. In any railway system with regenerative braking, the energy returned to the line at the substations is always only a small percentage of the energy regenerated at the trains, since much of the latter is absorbed in nearby motoring trains. The value of this percentage at the substations naturally varies according to the contour and traffic conditions on the line, and upon it depends the question of whether it is best in any given case to employ inverters, or to dissipate the surplus regenerated energy at the substations in resistances.

Conditions of heavy traffic generally tend to lower the percentage of regenerated energy at the substations, both because the forward energy figure is higher and because there is generally a better chance of the energy returned by a regenerating train being absorbed by a motoring train in the neighbourhood. The figures in Table I show that, excluding the special case of Booth substation, the energy regenerated at the substations averaged 12 per cent. of the forward energy for the year 1939. Consequently, in spite of the exceptionally heavy traffic of that year the readings show that in the case of this South African installation, where the main line handles 20,000 to 30,000 tons a day in each direction, the inverters were the correct choice.

* * *

The author is indebted to the South African Electricity Supply Commission and to the British Thomson-Houston Co. Ltd. for permission to publish the information contained in this article.

Electric Railway Traction

A Travelling Substation

AMONG the minor electrification activities of the Netherlands Railways within the past two or three years has been the construction and use of a mobile substation, and this has given such satisfactory results that a second one was ordered a short time ago in connection with the Amsterdam—Amersfoort extension, which was sanctioned at the end of last year. The existing plant, comprising a transformer, mercury arc rectifier, and associated switch and control gear, is housed on a special double-bogie chassis. It furnishes 1,500-volt d.c. to the contact line feeders when connected to the 10-kV three-phase supply, which is standard for much of the electrified area. The object was to have some reserve always available to augment the ordinary substations, or in emergency to take the place of one of them altogether. In view of the undesirability of allowing a rectifier to go unused for any length of time, this mobile plant has been used in conjunction with the static sub at The Hague, which is its home point, when not required to replace one of the plants along the remainder of the line.

Problems of Electric Traction

AMONG the unsolved problems connected with electric traction are the use of commercial-frequency a.c.; simplified overhead construction; and rheostat losses in d.c. control systems. These three questions, among others, were discussed at the last convention of the American Institute of Electrical Engineers. There are or have been several European attempts to use industrial-frequency alternating current, particularly in Hungary, where the Kando phase-converter system is used over the Budapest—Hegyeshalom main line in conjunction with 16-kV 50-cycle single-phase current. More recent locomotives, for example those on the Höllental line, have made use of rectifiers to change the high-frequency a.c. to d.c. for the traction motors. Maximum economic advantage by supplying electrified railways can be obtained only if the catenary system is fed with current at commercial voltage and frequency, and a joint industrial and traction feeder and distribution system of suitable design should not jeopardise the reliability of the railway service. A considerable cheapening in the cost of conversion could be gained by a simpler catenary construction, and the likelihood of more electrification would thereby be enhanced. Standardisation of current in the contact wire has already been established in many countries, but further economic gains without stultifying progress might be made by standardised h.t. feeder and conversion equipment. As a rule, the advantages of standardisation for electrical and mechanical components of locomotives have been fully appreciated on electrified railways of any magnitude.

On the question of d.c. control, the opinion generally is that the rheostat losses are too high, and in the discussion at the American Institute of Electrical Engineers it was stated that although the metadyne control developed in England reduced the rheostat losses and permitted regenerative braking, the complication, weight and cost seemed to offset these advantages. It was suggested that basic improvements could be made by adapting inverters and d.c. transformers of the commutator type to d.c. traction control. Electric braking of the regenerative type was considered almost ideal for holding trains on grades, but the dynamic system was more flexible in retarding a train, and in the experience of one company the heat developed in the braking rheostats reduced the cost of car heating by £25 to £50 a year per car, which was enough to offset the greater consumption of power brought about by the general rise in speed and acceleration rate. Another improvement desired was for a simple, efficient equipment to convert 600/650-volt d.c. to low-voltage a.c. for train lighting, battery charging, and auxiliary circuits, and the use of a vibrating inverter was suggested. Other improvements for which a need was expressed were lightweight batteries with a higher voltage per cell, better thermostatic control of heat on multiple-unit trains, less expensive d.c. lightning arresters for locomotives and multiple-unit stock, means for avoiding coatings of sleet on overhead wires, and a better system of station announcements for heavily-laden multiple-unit suburban trains.

Aluminium Feeder Cables

IN the October 13, 1939, issue of this Supplement we referred to the use of Aldrey aluminium-alloy cables for e.h.t. networks, but the use of this material and aluminium alloys generally has been covered more recently in a paper by Signor R. Righi, of the Italian State Railways, presented at the light-metal conference held in Milan a short time ago. The author emphasised first that the principal advantages of unalloyed aluminium in electrotechnology was its low specific weight, its resistance to corrosion, and its good conductivity, amounting to 61 per cent. of that of pure copper and 68 per cent. that of hard-drawn copper. Mechanical considerations had led to the adoption of steel-cored aluminium cable in place of that consisting entirely of aluminium. The steel-cored cable used in the transmission lines of the Italian State Railways comprised seven galvanised steel wires over which were wound 22 aluminium wires, the steel to aluminium ratio being 1 : 2 in respect to weight and 1 : 6 on the basis of cross section. Aluminium-magnesium-silicon alloys of the Aldrey type had been used for similar purposes, and although the conductivity was somewhat less than that of unalloyed aluminium, the mechanical strength was double, and was about 50 per cent. greater than that of copper. Contact wires were still made of copper, but their stay wires were often of aluminium alloy, and in the large electrified track mileage associated with the new terminal station at Rome and its approach lines, considerable use was being made of aluminium alloys in the overhead system and fittings. Signor Benoffi, of Turin, stated that experiments were being made with aluminium-steel contact wires, but so far had not been particularly successful. The wear was greater and there were difficulties in handling and manipulation, especially in unwinding from the drum. Another speaker considered that steel-cored aluminium cables could replace copper for contact wires, at least where current collection was through trolley wheels. The wear was rapid until the steel became visible and the wire had assumed a profile corresponding to the wheel, after which the wear was negligible.

THE PENNSYLVANIA RAILROAD ELECTRIFICATION

A continuation from page 37 of the March 29 issue of a description of the world's largest electrified system

THE previous instalment of this article dealt with the extent and various stages of the 11-kV 25-cycle single-phase electrification of the Pennsylvania Railroad, and the power supply and transmission arrangements.

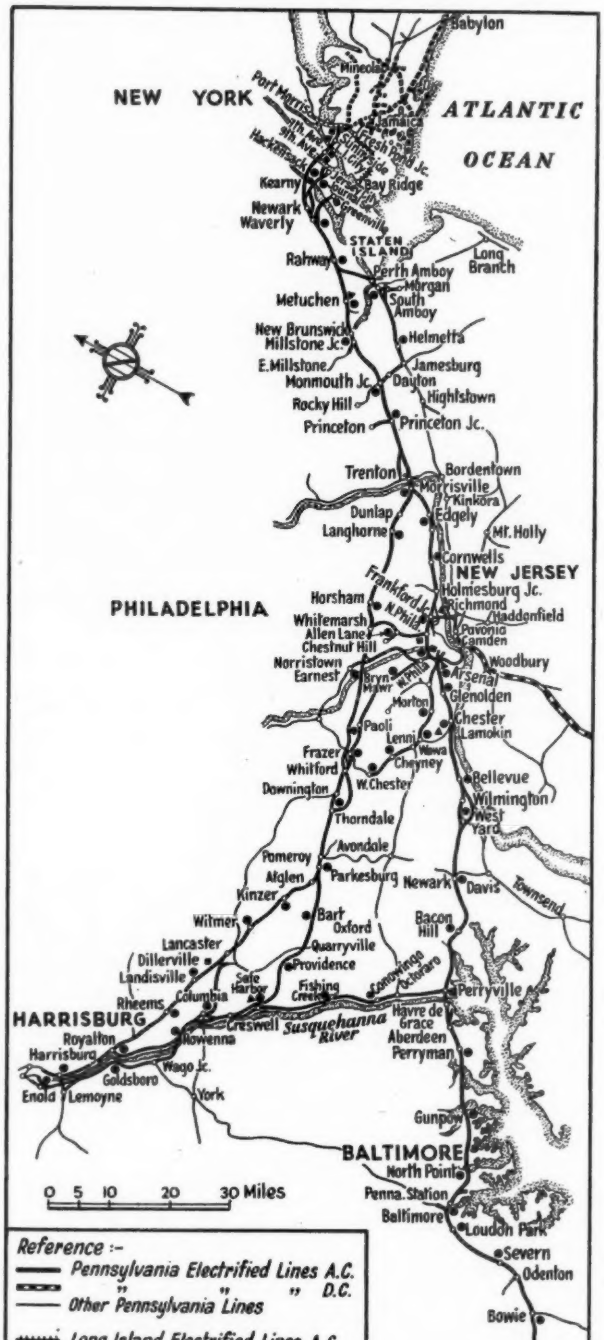
Substations

In addition to the seven power supply points detailed in the first instalment of this article, the present a.c. electrified system is fed through 68 traction substations, or more correctly, transformer stations. Three of the traction subs also have e.h.t. transmission switchgear, and there are four further subs dealing with e.h.t. current only. Finally, there is one condenser substation. The ordinary traction substations step down the e.h.t. current from 132 kV to the 11 kV at which it is supplied to the overhead line, and they are located on the average about eight to ten miles apart. A transformer size of 4,500 kVA has been standardised.

Prior to the Harrisburg extension, the running lines of the 373 miles of route electrified were fed through 40 transformer stations containing 152 transformers, of which 134 were of the 4,500 kVA size. The aggregate continuous rating was 659,000 kVA including 26,000 kVA of step-up apparatus which fed 44-kV circuits from the 11-kV busbars at two stations. In addition there were seven subs for feeding yard and terminal lines. The Harrisburg extension included the erection of 21 new substations, additions to two of the supply points, and additions to certain existing substations. On the continuous rating the aggregate capacity of the transformers now feeding the entire Pennsylvania a.c. electrified system is approximately 1,000,000 kVA.

In the original transforming stations the equipment included water-cooled transformers, but present standards consist of self-cooled oil-insulated transformers located out of doors. An ample overload capacity has been provided, and in respect to both bushing and internal insulation their design has been carefully co-ordinated with that of the transmission system to obviate failure due to excessive voltage. The newest transformers have a high impulse-voltage rating. Protection schemes on the earlier electrifications made use of choke coils and electrolytic lightning arresters, but in the more recent conversions these have been replaced by co-ordinating gaps and arcing rings, or the transformers are connected to the transmission circuits by means of horn gap switches without circuit breakers.

On the 11-kV side the transformers are connected to the overhead line bus through circuit-breakers, and the bus is divided into two sections by a bus tie circuit-breaker to sectionalise the catenary system in each direction from the substation. The catenary over each track is fed separately through a high-speed circuit-breaker. Formerly this breaker was of the oil type operating at a comparatively low speed, and because of this a short circuit sometimes resulted in the burning down of a contact wire. The present breakers contain very little oil; they are rated at 1,500 amp. continuously and can interrupt short-circuit current in less than one cycle on a 25-cycle basis, or approximately 0·04 sec. On the New



Map of the Pennsylvania a.c. and d.c. electrified routes

York to Washington electrification the interrupting capacity of a breaker was 50,000 amp., but owing to the increase in the system capacity, 100 of the breakers ordered in connection with the Harrisburg extension have a capacity of 65,000 amp.

In addition to the transformer stations feeding the catenary systems above the running lines there are eight similar stations for feeding the tracks in large freight yards or in terminal areas. The large number of circuits in such places has led to an arrangement in which a high-speed breaker feeds a busbar from which lead a number of sections by a circuit-breaker of low rupturing capacity, and suitable only for handling load currents. When a fault occurs the high-speed breaker opens, and after the circuit has become de-energised the low-capacity breaker opens the section at fault; after this the high-speed, or master, breaker recloses, restoring power to the overhead line sections unaffected by the fault.

Remote Control

In general, the substations built for the New York to Washington and previous electrifications are remotely-controlled from the nearest signalbox, but between Wilmington and Washington exceptions were found to be desirable, as the most suitable location for certain substations was not adjacent to a signalbox. Therefore, six substations on that section are equipped with supervisory remote control under the control of the area power director. This method of operation has been found considerably faster and more efficient and reliable than the older system of transmitting orders and reports by telephone to and from the signalbox, and the principle has been continued for the 21 substations of the Harrisburg extension, making a total of 35 substations on the Pennsylvania a.c. system which have supervisory control.

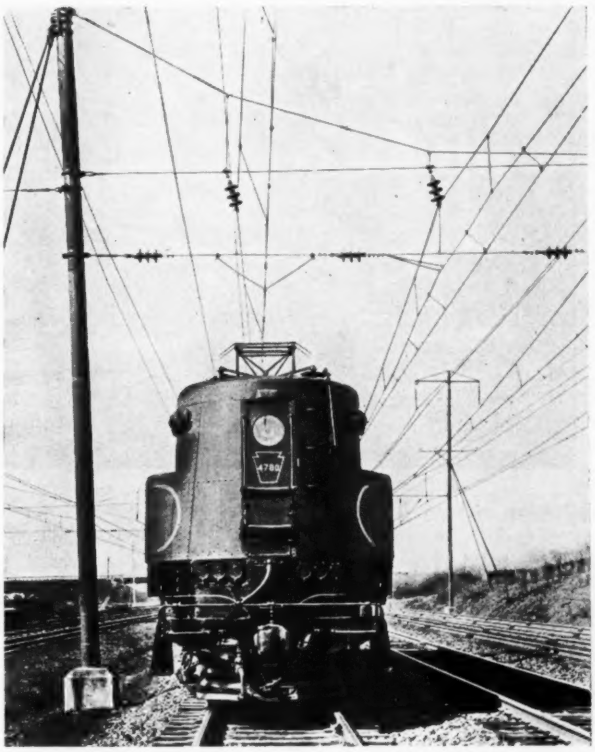
On the Harrisburg extension, 18 of the 21 substations are located in one operating division, and are controlled from a room at Harrisburg. Two of the three remaining subs were incorporated in an existing supervisory control system, and the last sub, feeding a freight line, is operated from a nearby signalbox. For purposes of control, the 18 subs in the Harrisburg division are grouped in two zones, each of which comprises about half the passenger lines and half the freight lines. A further subdivision is made into two metering groups in each zone, separating the passenger from the freight line subs. A two-wire code type of supervisory control has been installed, and normally each sub is operated over a separate pair of telephone wires. Each metering group is furnished with a spare pair of wires for emergency use for any substation in the group, and operation can be transferred to these spare wires by remote means from the control room.

There are four sets of meters installed in the control room—one for each group—and indications are brought over one pair of metering wires for each group. Any one meter reading in each group may thus be obtained at the same time without interfering with the normal supervisory system. The six readings which may be obtained are:

(1) 11-kV 25-cycle substation catenary feeder bus voltage.
(2) 125-volt substation control battery voltage.
(3) Substation supervisory control battery voltage.
(4) 25-cycle main power transformer current.
(5) 44-volt 100-cycle signal power generator voltage.
(6) 100-cycle signal generator current.

The last two indications are obtained only from those substations in which are housed signal power frequency-changer sets.

In the older parts of the electrified area, with substations controlled from signalboxes, each electrical division has a power director responsible for all voluntary switch movements or operations in the substations. There is a complete telephone service upwards to the signal superintendent and downwards to all points of control, to train dispatchers, and to the telephone boxes along the track. Each power director has a model board on which the circuits in his area are shown in miniature with manually-operated red and green lights to show the positions of all switches and breakers.



Standard cross-catenary suspension for four or more tracks, and front end of a P-5A express electric locomotive

This old system of control is worked in conjunction with a centralised supervision over the transmission circuits and power supply, so that manipulation of the switches and circuits locally does not interfere with inter-divisional circuits, and so that the supply of power may be controlled economically and effectively over all the electrified lines. This supervision is in the hands of a system load dispatcher located at Philadelphia, and who reports to the electrical engineer of the railroad. The mimic diagram in the Philadelphia office shows the power supply points, e.h.t. circuits, and substations over the whole electrified area, but not local circuits. Part of the equipment consists of an elaborate telemetering system to enable the load conditions and division of load among the various supply points to be followed.

Overhead Construction

Owing to the amount of four-track route on the Pennsylvania electrified system, cross-catenary overhead construction is the favourite, and the supporting structures are located at about 265-ft. intervals. At certain points a cross beam is used instead of the cross catenary, and on single-track or double-track routes a single pole with cantilever arm or arms is used. In all three types the

Cross-catenary overhead construction at Washington station. The train, hauled by one of the GG-1 express locomotives with the 2-Co-Co-2 wheel arrangement, is the President

design in general is somewhat complicated through the transmission and signal wires being carried on the masts. Further, the design is one which gives longitudinal and torsional flexibility combined with great transverse strength.

As may be seen in one of the accompanying illustrations, which shows also the front end of one of the P-5A passenger locomotives, the cross catenary is supported by steel poles set in concrete foundations and suitably guyed. Tubular poles were used in the earlier electrifications, but I-beams are the present-day standard. Usually the pole foundations consist of a metal tube sunk in the ground and back-filled with concrete after the pole has been inserted and aligned; the top surface of the foundation is dressed off by metallic split forms. Most of the guy anchors consist of cast-iron cones, but when greater strength is required a reinforced concrete anchor is poured in place.

Between the poles (or masts) the cross structure supporting the contact wire includes the cross catenary; just below it the horizontal body span which takes the side load in the main messenger; and a second horizontal steady span, complete with insulators, which prevents excessive lateral movement of the contact wire. Below are the longitudinal catenary (main messenger), the auxiliary messenger, and the contact wire. All the cross wires are of stranded bronze, the steady span being $\frac{7}{16}$ in. in diameter and the others varying from $\frac{5}{8}$ in. to 1 in. depending on the loads to be supported. All these strands arrive on site cut to length and equipped at each end with swaged or drawn fittings. Adjustments are made by turnbuckles. The mast guys are of galvanised high-tensile steel strand of $\frac{7}{8}$ in. to $1\frac{1}{8}$ in. diameter.

It is claimed that on multi-track routes the cross-catenary form gives greater signal visibility and is less costly than the cross beam, or self-supporting, type necessary where it is not practicable to use guyed structures. From the illustration of this form it will be seen that the cross beam is stiffened by sag braces, and that the cross system includes both a body span and a steady span; the insulators for the longitudinal catenary are suspended from the cross beam.

On the 1915-18 electrifications in the Philadelphia suburban area the messenger of the catenary system above the tracks was of $\frac{1}{2}$-in. galvanised steel wire, but a few years of experience proved that this material was subject to rapid corrosion, particularly where steam trains were using the same tracks, and in later conversions a $\frac{5}{8}$-in. messenger of high-tensile bronze has been used, and stretched to a normal tension of 4,640 lb. This material is either a silicon-tin-copper or aluminium-tin-copper mixture with an ultimate strength of 115,000 lb. per sq. in.

The standard auxiliary is of 4/0 American w.g. grooved copper strung to a tension of 1,200 lb., and serves the dual purpose of principal current-carrying member and of acting as an intermediate messenger to give additional flexibility. The auxiliary is supported from the messenger by bronze hanger rods spaced 30 ft. apart, and varying in length from less than 3 in. at the centre of the span to about $4\frac{1}{2}$ ft. near the cross supports. The contact wire is of 4/0 American w.g. grooved bronze (tin-copper or cadmium-tin-copper) strung to a tension of 3,500 lb. The contact wire is supported from the auxiliary by means of clips spaced 15 ft. apart and staggered in relation to the hanger rods above. Clips are of cast bronze containing tin and nickel; formerly bronze carriage bolts with split ends were used for the clips but hollow copper rivets are the present practice.

Above the freight tracks a simpler catenary system is erected. The auxiliary is omitted, and the contact wire is suspended directly from the messenger by lifting-type hangers. To compensate for the loss of conductivity through the elimination of the auxiliary, a composite messenger is used, and it has 12 copper wires on the outside and a core of either bitumen-coated galvanised steel, copper-covered steel, or high-tensile bronze wires. Further, the contact wire has a conductivity of 55 per cent. compared with 40 per cent. in the compound

catenary system. On curves a slanting catenary arrangement is used, as shown in the illustration of one of the Philadelphia multiple-unit suburban trains.

Insulation of the longitudinal catenary system over each track consists of three 10-in. cap and pin suspension insulators, each 5¾ in. in length. The contact system over each running track is independent of those alongside except through the circuit-breakers in the substation busbars, but is sectionalised at cross-overs and other points; most of these section breaks are bridged by contact-wire sectionalising switches, some manually and some electrically controlled.

Track Bonding

The traction current is returned through the running rails, which on much of the electrified area are of the Pennsylvania's standard 131-lb. and 152-lb. types. The standard rail bond now consists of two parallel strands each made up of seven steel and 10 copper wires with the ends butt-welded to tapered steel plugs. These plugs are driven into ⅞-in. holes in the rail webs. The copper strands are tinplated and the whole bond has the appearance of a galvanised steel signal bond; this has greatly reduced the theft of bonds, which at one time was a source of considerable expense and trouble where all-copper bonds could be observed.

Continuity of the return path for the traction current round the insulated joints forming part of the signal system is maintained by impedance bonds. In effect, these are composed of two auto-transformers connected across between rails on either side of the insulated joint and with their mid points connected together. The impedance to the flow of traction current is therefore effectively neutralised, whereas a high impedance is maintained between the rails for the signal circuits.

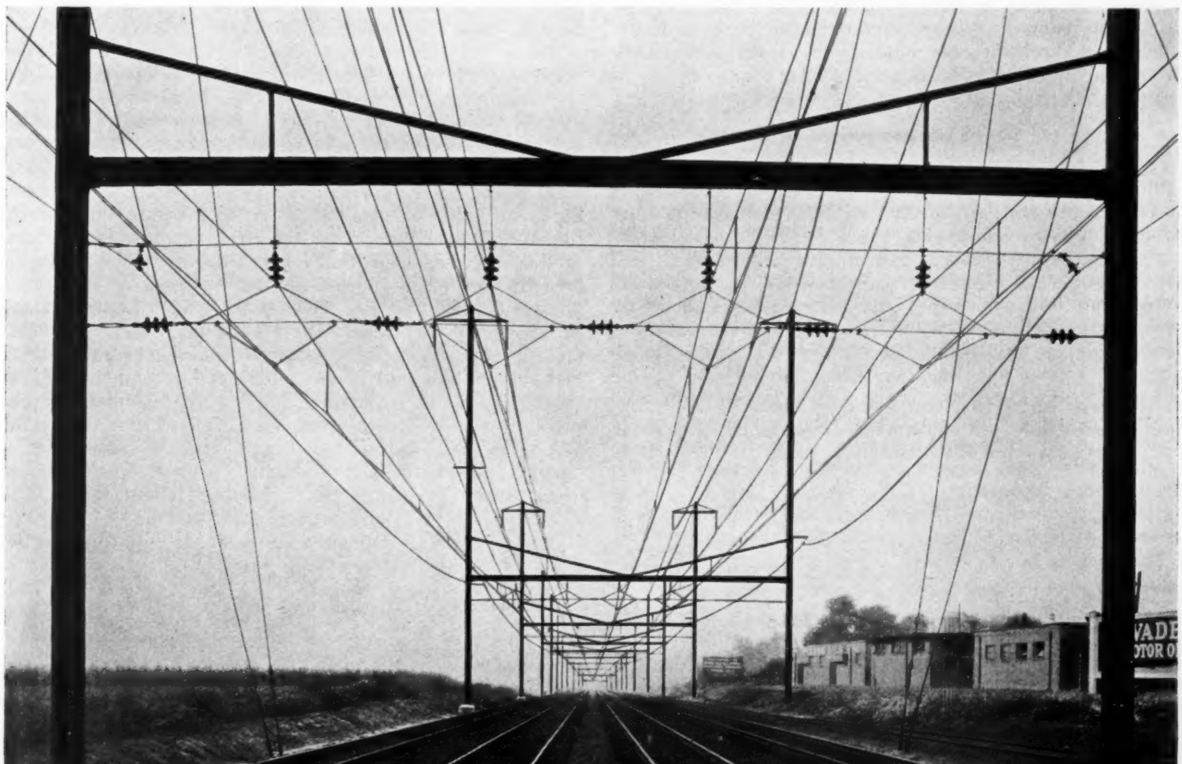
Signalling

Transmission of signal power is through a single-phase 100-cycle, 6,600-volt circuit carried on the catenary masts at about the level of the body span. The insulators are of the 27-kV pin type and the 1/0 American w.g. copper conductors are spaced about 7 ft. apart horizontally. This circuit is tapped through transformers at signal posts and gantries, and it also furnishes a certain amount of energy for station lighting and level crossing signals.

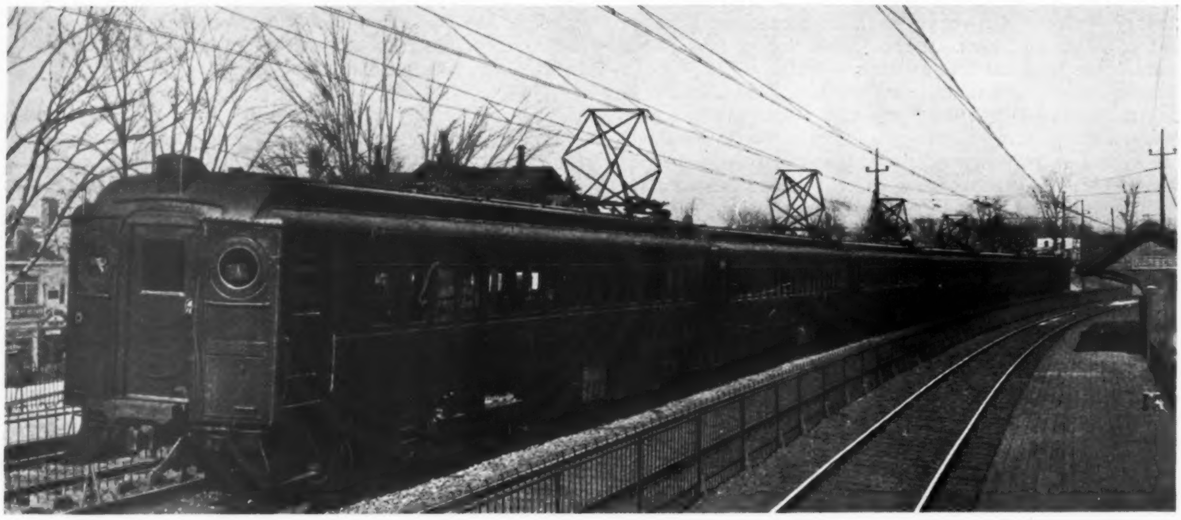
A universal code signal system has been adopted. Colour-light signals are used, and miniature signals of similar appearance in the cabs of the electric locomotives give the driver constant advice as to the signal position. The indications are given by means of intermittent impulses of the 100-cycle current in the rails, and these impulses are transmitted by physical connections to the signal and are picked up by a detector bar on the locomotive. Tuning and amplifying equipment supplements the visual cab indications by audible warning. This signal system is unaffected by stray currents of other frequencies, and even stray current of the same frequency would have to be imposed on the rails at the proper intermittent coded impulses before a false clear signal could be given.

Communication Circuits

Before the New York—Washington electrification, sectional openings of which began in 1930, the railroad's telegraph and telephone circuits were carried in open



Cross-beam type of overhead construction for quadruple-track 15-kV single-phase lines



Six-car multiple-unit suburban train passing Narberth station near Philadelphia, Pennsylvania Railroad

wires on poles close to the track; but for that conversion scheme these communication circuits were placed in cable and carried in underground ducts in order to eliminate interference and give protection against severe weather conditions. To provide equal results and reliability at a lesser cost, however, the communication circuits on the Harrisburg extension have been brought back over-ground, and are carried in armoured cable on treated wood poles alongside the track. The circuits have been carefully loaded and balanced to give communication superior to the older types, and the new cables provide for the supervisory and metering control circuits of the substations, as well as for the railroad's general communication lines.

Locomotives

The modern electric locomotives of the Pennsylvania Railroad have already been described in detail in past issues of this Supplement, principally in those dated September 18, 1936, and November 12, 1937. Locomotive construction on the Pennsylvania began in 1905 when two experimental double-bogie locomotives were built at the Juniata shops, and tried out over a d.c. test track on the West Jersey & Seashore Railroad. Three years later an experimental 15-cycle single-phase locomotive and motor-coach were run over a test track on Long Island, and in the following year, 1909, two big 2-B-B-2 d.c. experimental locomotives were built, and were the harbingers of 24 others built in 1910 for the New York terminal area. Another seven were built subsequently and were the last Pennsylvania locomotives intended solely for d.c. working; all d.c. locomotives after that time were designed for easy conversion to 11-kV 25-cycle single-phase. These 33 locomotives were classified as DD-1.

In 1917 a 4,000 h.p. 1-C-C-1 single-phase locomotive, classified as FF-1 but known throughout the Pennsylvania system as " Big Liz," was introduced into freight service between Philadelphia and Paoli, passenger traffic over which route had been operated by single-phase multiple-unit trains since 1915. Seven years later three test locomotives with the 1-BB-1 wheel arrangement were built for trial in both passenger and freight service according to the ratio of the gears fitted; they were classified as L-5, and one was intended primarily for operation on a.c. and two for d.c. Another 21 of the d.c. type were put into traffic shortly after, but this was the last locomotive design prior to the first-magnitude single-phase main-line electrifications from New York to Washington and Harrisburg. With the improvement in motor design it became practicable to give up rod drive in favour of double-armature motors transmitting their torque through individual axle drive, and in 1930 a twin-motor 2-Bo-2 type, classified O-1, of 2,500 h.p. was built for ordinary passenger work. In 1931 the design was developed into a 2-Co-2 unit of 3,750 h.p., class P-5, and in 1932 a 2,500 h.p. 1-Do-1 freight locomotive with four axle-hung motors, class L-6, was built.

Trials and long-period observations on these classes between New York and Philadelphia indicated that the O-1 class would have but little scope in view of the weight and projected acceleration of passenger trains when the line was electrified through to Washington, and that freight traffic would really require more powerful and more speedy locomotives than the L-5 units. Moreover, the principal expresses would require bigger locomotives than the P-5 batch. After the trial locomotives, 62 units of the P-5 class were built, and a further 28 were under construction when it was decided to transfer from passenger to freight service 58 of the 2-Co-2 locomotives and substitute 58 others of a new and much more powerful design. The 28 engines under construction were modified to have a single cab in the centre and a semi-streamlined contour, and were classified P-5A. In 1934 two experimental express locomotives were turned out, one, the R-1 class, a 2-Do-2 of 5,000 h.p., and the second, GG-1 class, a 2-Co-Co-2 with a maximum short-time rating of about 9,000 h.p. The GG-1 has been standardised, and an order for 57 locomotives was sanctioned in 1934. Batches of 11 and 20 have been acquired subsequently. Prior to the Harrisburg extension, another experimental design, class DD-2 (wheel arrangement 2-Bo-Bo-2), was tried, but showed no advantage over the GG-1 type. There is also a six wheel Co shunting locomotive class B-1, with axle-hung motors.

The P-5 locomotives have been changed over gradually to class P-5A, and the motive power for main-line passenger and freight trains now consists of 91 class P-5A and 89 class GG-1 locomotives. The earlier P-class engines had a gear ratio suitable for a top speed of 90 m.p.h., but 63 of the P-5A total now have 70-m.p.h. gearing, and the remainder 90 m.p.h. All are normally used in freight operation, but can be used for passenger traffic peaks, when the freight service normally is reduced. Conversely,

the GG-1 class is assigned to passenger traffic, but engines of this class can be used in heavy freight service.

Suburban services in the New York and Philadelphia areas, and slow services over such sections as Washington—Baltimore and New York—New Brunswick, are worked by multiple-unit trains. In the earlier trains each vehicle was a motor-coach powered by two motors with an average individual capacity of 200 h.p., which was sufficient to give an acceleration of 1.0 m.p.h.p.s. and to maintain speeds of 45 to 65 m.p.h. continuously. Beginning in 1930, that is when sectional openings of the New York—Washington route were being inaugurated, a decision was made to use two-car sets comprising a motor-coach and a trailer, and the two motors in these power cars have an individual continuous capacity of 370 h.p. and are both mounted on one bogie. The motor voltage is 850 maximum, and on the secondary side of the transformer on the coach there are numerous taps connected to unit switches for controlling the motor voltage during acceleration. Current is also supplied through taps to the motor-blower group, the compressor, motor-generator set, and car heaters.

Traffic and Energy Consumption

The yearly current consumption of the a.c. system is over 1,000 million kWh. After the New York to Washington electrification, current consumption for the first full fiscal year was 526,870,545 kWh., but the full freight service was not operated electrically throughout the year, and the equivalent consumption at that time was probably over 600,000,000 kWh. The maximum one-hour demand was 142,700 kW. For the year just mentioned, when 373 route miles were electrified, the daily electric operation totalled 50 through freight and over 650 passenger trains, including 450 multiple-unit trains in the New York, Philadelphia, Baltimore and Washington areas. The passenger service showed 12,145,293 multiple-unit car-miles, 83,330,290 passenger-car miles, and 8,806,376 electric locomotive miles. Over the same period electric freight traffic produced 2,820,565,000 gross ton-miles (short tons) and 2,046,687 locomotive miles, and over 1,000,000 electric locomotive miles were required for switching and other services. The Pennsylvania Railroad's own estimates for the expected full service over the New York—Washington route and associated suburban and freight lines showed an annual freight traffic equivalent to 10,030,000,000 gross ton-miles (short tons), a passenger-car mileage of 133,575,000, and a locomotive mileage of 17,787,000.

MILESTONES IN PENNSYLVANIA ELECTRIFICATION PROGRESS

Camden—Atlantic City*	1906
Manhattan Transfer—New York—Sunnyside (d.c. working) ...	1910
Philadelphia—Paoli (passenger)	September 12, 1915
Philadelphia—Chestnut Hill (passenger)	March 30, 1918
Allen Lane—Whitemarsh (passenger)	February 27, 1924
Philadelphia—Wilmington (passenger)	September 30, 1928
Philadelphia—West Chester (passenger)	December 2, 1928
Philadelphia—Trenton (passenger)	June 29, 1930
Philadelphia (52nd. Street)—Norristown (passenger)	July 20, 1930
Manhattan Transfer—Penna. Stn. (N.Y.)—Sunnyside Yard (turned over from d.c. to a.c. working)	January 23, 1932
Jersey City—New Brunswick (local passenger)	December 8, 1932
New Brunswick—Trenton	January 16, 1933
New York—Philadelphia through passenger service	January 16, 1933
New York—Wilmington through passenger service	February 12, 1933
New York—Wilmington through service re-routed through new station at 30th Street, Philadelphia	March 12, 1933
New York—Philadelphia—Paoli through passenger service ...	April 9, 1933
Wilmington—Washington	February 10, 1935
New York—Washington partial through passenger service ...	February 10, 1935
New York—Washington complete through passenger service ...	April 7, 1935
New York—Washington partial through freight service ...	June, 1935
Paoli—Harrisburg (*via* Lancaster)	January 15, 1938
New York—Philadelphia—Harrisburg through passenger service	January 15, 1938
All passenger traffic on Philadelphia—Harrisburg extension ...	End of January, 1938
Freight service on Harrisburg extension lines	1938

* West Jersey & Seashore Railroad, a subsidiary of the Penna. ; now electrified only between Camden and Millville.

PENNSYLVANIA ELECTRIFIED MILEAGE

		Mileage		System
		Route	Track	
1910–35	New York—Washington ; Philadelphia and New York suburban	373	1,343	1/11/25
1938	... Harrisburg extension, comprising Paoli — Lancaster — Harrisburg ; Pomeroy—Royalton ; Shock's Mills —Enola ; Columbia — Perryville ; Morrisville—Paoli ; Monmouth Jct. S. Amboy ; Frankford Jct.—Pavonia	315	773	1/11/25
1906	... Camden—Millville	40	110	650 D.C.
	Total	728	2,226	

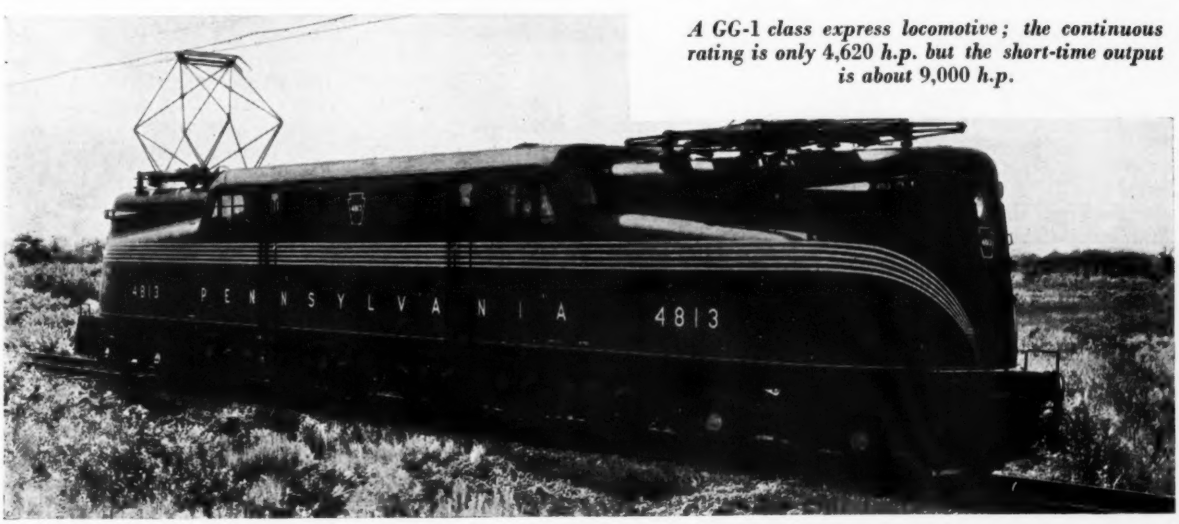
LONG ISLAND R.R. (PENNA. SUBSIDIARY)

		Route	Track	System
1932	... Bay Ridge—Fresh Pond Jct.	12	85	1/11/25
1905–38	New York to Rockaway Park, Babylon, Mineola, Port Washington, Long Beach, and connecting lines	141	448	650 D.C.
	Total	153	533	

NEW YORK CONNECTING RAILROAD (PENNA. AND N.Y.N.H. & H. JOINT)

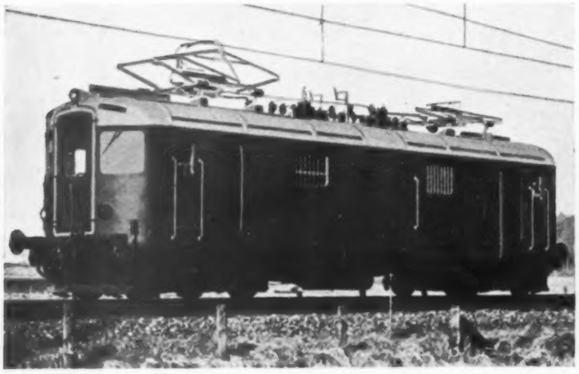
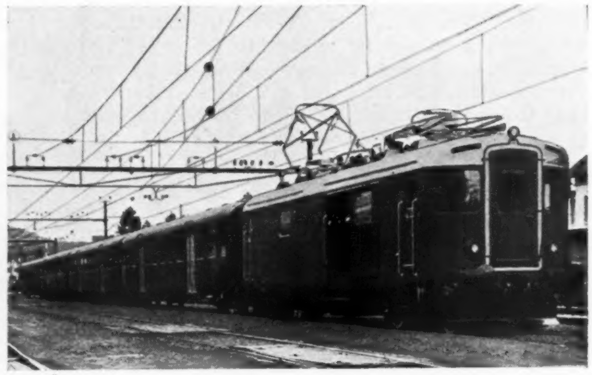
		Route	Track	System
1932	... Port Morris—Sunnyside—Freshpond Jct.	9	65	1/11/25

The maximum mileage run by the GG-1 class electric locomotives appears to be about 14,000 a month, and the total mileage made by the first 58 locomotives of this type in the first complete year of their service was 6,968,581. This performance is being maintained, and in the first three years the mileage was in excess of 21,000,000, giving an average yearly mileage per locomotive of 120,000.



A GG-1 class express locomotive ; the continuous rating is only 4,620 h.p. but the short-time output is about 9,000 h.p.

NEW EXPRESS MOTOR-VANS IN SWITZERLAND

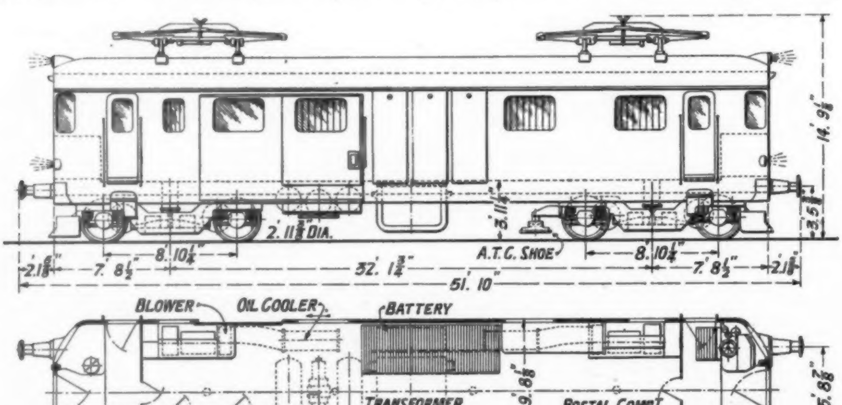



Two views of the new motor-coaches built for express services in Switzerland

THREE high-speed motor-vans, Nos. RFe 4/4, 601-03, for haulage of lightweight expresses, primarily between Geneva and Zurich, were ordered in December, 1937, by the Swiss Federal Railways, and have now been delivered and undergone the usual trials. They represent a new departure for this system, which hitherto has used locomotives exclusively for long-distance trains and did not have very satisfactory results with the heavy motor-coaches and motor-vans placed in service some years ago for local train haulage. The new motor-vans are designed for multiple-unit working.

The electrical equipment of the motor-vans was, as is now usual, produced by Oerlikon, Brown Boveri, and Sécheron, the latter building the motors for two of the vehicles, and the individual axle drives for all three being supplied by Brown Boveri; Oerlikon provided the remaining equipment and fitted the whole of the electrical portion into the bodies and bogies built by the S.L.M., Winterthur.

In accordance with the practice inaugurated with the 12,000 h.p. Gotthard locomotive and the latest diesel locomotives, the new vans are rounded at the ends and their lines harmonise with those of the coaches they are designed to haul. The maximum speed is 125 km.p.h. (77½ m.p.h.), and on the one-hour rating they develop 1,340 h.p. at 91 km.p.h. (56½ m.p.h.) with a tractive effort of 3,900 kg. (8,600 lb.); the continuous output is 1,250 h.p. at 93 km.p.h. (58 m.p.h.). The maximum starting tractive effort is 6,400 kg. (14,200 lb.). The tare is 48.5 *tonnes* and the maximum loaded weight 52 *tonnes.* In addition to a luggage compartment of 23 sq. m. (247 sq. ft.) surface a portion of the electrical equipment is fitted inside the van, and the transformer and switchgear are fitted underneath, and the starting and braking resistances are housed inside a double roof. The control system embodies 20 notches for running and 20 for electric braking on resistances. The driving compartment at each end is provided with a standard vestibule connection, so that the vans may be inserted at any point in the train. There are two pantographs, one only being in normal use. The usual dead-man pedal equipment is included, as well as the automatic train control apparatus, the latter being so arranged that in multiple-unit operation only the driving van is under control. The self-ventilating motors, two to each bogie, are generally similar in design to those of the three-car high-speed trains described in our issue of December 10, 1937, and of the new twin-unit Red Arrow railcar. The wheel diameter is 900 mm. (35½ in.) and the gear ratio is 1 : 3.17. Automatic air brakes are fitted and are arranged to give a maximum pressure equivalent to 150 per cent. of the braked weight at speeds above 80 km.p.h. (50 m.p.h.), reduced to 60 per cent. at speeds below 40 km.p.h. (25 m.p.h.).



General arrangement of one of the new Swiss Federal Railways double-bogie motor-coaches designed to haul up to three 29-ton all-metal coaches and to be operated in multiple-unit when traffic conditions necessitate

NEW BELGIAN ELECTRIC TRAINS

Two-car sets for accelerated stopping trains between Brussels and Antwerp have been provided with a new type of bogie in order to improve the riding

FROM its inception in 1935 until October of last year, the electrified line between Brussels and Antwerp on the Belgian National Railways carried only non-stop and one-stop trains, but with the inauguration of last winter's timetables a comprehensive service of stopping trains was added. To operate the new services eight two-car non-articulated all-steel trains were built ; they weigh about 104 *tonnes* and have a top speed of 75 m.p.h. In the old trains the motor-coaches weighed 71 *tonnes* and the trailers 44 *tonnes*. Further, 16 new trailers have been built so that the existing four-car fast train sets can be made up into six-car formations.

In general, the design of the new two-car sets has followed that of the 1935 stock, and has traction motors entirely springborne and driving the 44-in. wheels through the Sécheron form of individual axle drive. The motors were supplied by the S.E.M., of Ghent, and the individual axle drives by the A.-C.E.C. In the 1935 stock the bogie was of the ordinary double-suspension pattern, but the clearance between the axle and the hollow quill was not great enough for the vehicle suspension to give the desirable comfort to the passengers. Therefore, in the new stock the design has been altered to give the requisite flexibility, to reduce the amount of unsprung weight and thus lessen the track stresses, and to enable the motor to be dropped and re-inserted without dropping the wheels. As with the 1935 stock, the design and construction of the mechanical parts and the bogies of the new trains has been largely in the hands of the Ateliers Métallurgiques de Nivelles.

The latest design makes use of two independent suspension systems, comprising equaliser bars extending between the axleboxes and supported on double helical springs, and above this ensemble a bolster on the helical springs, but carried also by four full-elliptical laminated springs on each side. At the buckles of the laminated springs are slides having the working surfaces running constantly in oil. The weight of the car body is taken first by rubber-cushioned side bearers, and the hemispherical centre pivot bears no weight.

The traction motors are carried rigidly, being supported at two points on the inner transom of the welded steel bogie frame, and by a cylindrical trunnion supported on the outer headstock. The motor thus more or less floats on the axle ; the bogie frame structure itself is supported primarily through laminated springs above the axleboxes, and the buckles of these operate in oil-bath cushions. The top members of the bogie frame structure are of box-girder section.

The bogie wheels are of the tyred disc pattern with suitable lugs on the cast steel centres to take the six helical steel springs of the individual axle drive. They are spread over a base of 10 ft. 2½ in. The axles are supported in S.K.F. roller bearings, and between the wheels have a diameter of 7·1 in. compared with the inside diameter of 9·3 in. of the surrounding hollow quill. The horn stays on each side are connected by an adjustable steel bar. Westinghouse compressed air brakes are used to apply clasp rigging and two blocks on each wheel. The maximum force at top speed is equivalent to 160 per cent. of the braked weight.

Emergency Substations

In accordance with the provisions of Section 42 of the Civil Defence Act, 1939, the Central Electricity Board has established throughout the country stores of equipment upon which to draw in emergency in order to build temporary transforming and switching stations. The ready availability of this equipment was recently demonstrated by the trial erection on an industrial estate near London of a 20,000-kVA substation taking current from an adjacent 33-kV overhead transmission line. The site selected was a piece of rough and relatively soft ground about 30 yards from a properly constructed road. Haulage contractors provided the necessary transport and the board's own stores provided the necessary transformer foundation sleepers and the steel plates for enabling the heavier items to be taken over the more yielding stretches comprising the last stage of the journey. All the material for the substation had to be brought from a distance of 20 miles. Loading started at 7.30 a.m. on the first day and the station was ready for use and made alive by 6 p.m. on the following day. No work was done after dark, the actual time taken for erection being 19 working hours. Because cable jointing requires time, the emergency switchgear is arranged to permit the erection at an early stage of all parts requiring connection with feeder circuits. In the station under consideration the work of cable jointing might have been started within three hours from the commencement of erection, leaving 16 more working hours available for its completion. Single-core cable is provided by the stores with all accessories and jointing material. Use is made of specially developed emergency cable joint-boxes filled with cold-setting compound.

In the substation noted above tappings from the overhead line were brought to an auxiliary pole and thence to a 20,000-kVA transportable transformer. In this unit oil cooling is effected by Serck radiators of the automobile type mounted on one side. Motor-driven fans and pumps are provided for circulating the air and oil respectively. The 400-volt 3-phase supply for the motors is given by an auxiliary transformer attached to the main unit. The main transformer's secondary provides either 11 kV or 6.6 kV. In the arrangement demonstrated it was connected *via* a circuit breaker and isolating links to busbars from which were taken off three feeder connections *via* further isolating links and circuit breakers. The galvanised steel angle-iron framework supporting the switches, the busbars and other items is made up of numbered components which can be assembled in a variety of ways to give any required layout. The work of assembly is done on the site from an isometric drawing, this being thought more easy to follow than orthodox engineering projections in this class of erection. The vertical members stand on feet which are drilled to take long galvanised holding down spikes. All frames, switch cases, transformer housings, etc., are bonded together with flat copper strip laid on the ground and connected at various points to galvanised earthing tubes. The earth resistance is made as low as possible, one ohm being considered a reasonable value.

NOTES AND NEWS

Italian Electrified Lines.—Since the opening at the end of October last of Milan-Chiasso, Milan-Voghera- and Falconara-Orte lines, the electrified route mileage of the Italian State Railways has been approximately 3,150.

Lightweight Pantographs.—At the light metals conference held in Milan a short time ago it was stated that pantograph structures of an aluminium-silicon alloy were being tried by the Italian State Railways.

Swiss Energy Consumption.—The energy consumption of the Swiss Federal Railways during the first nine months of 1939 was 469 million kWh, of which 410 million kWh were generated by stations belonging to the S.B.B.

Proposed Swedish Extension.—The Bergslagen Railway is proposing to extend its present 102-mile electrified system between Gothenburg and Åmål a further 44 miles from Åmål to Kil. Single-phase 16-kV $16\frac{2}{3}$-cycle current is used.

Swiss Train Rebuilt.—One of the two high-speed lightweight three-car trains of the Swiss Federal Railways (described and illustrated in our issue of December 10, 1937), which was partly destroyed by fire in the Rorschach shed in August last year, is being rebuilt as a two-car unit.

Brazilian Electric Locomotive.—The Central Railway of Brazil has assembled in its own shops a small electric locomotive for shunting service and light duties. It is understood that standard Metro-Vick motor-coach bogies and control equipment from the suburban stock have been incorporated.

Chilean Underground.—A decree passed by the Chilean Government raises from 10,000,000 to 14,000,000 pesos the authorised sum for the construction of an underground electric railway to join the terminal stations in Santiago of the Southern and Central systems of the State Railways.

N. W. Storer.—The 1939 Lamme medal of the American Institute of Electrical Engineers has been awarded to Mr. N. W. Storer, retired consulting railway engineer to the Westinghouse Electric & Manufacturing Co. Ltd., for "pioneering development and application of equipment for electric traction."

U.S.S.R. 50-Cycle Locomotive.—The experimental single-phase industrial frequency 20-kV electric locomotive described in the issue of this Supplement for December 8, 1939, has been running on an experimental track at Butovsk, near Moscow. It is said that trains up to 1,000 tons in weight were hauled.

Swedish Electrification Openings.—During the year 1939 the following lines were opened to electric traction: Ånge-Bräcke-Östersund (102 km.); Bräcke-Långsele (131 km.); Gothenberg-Olskronen-Uddevalla (87 km.). The electrification work on the section between Långsele and Vännäs, which was due to be opened on May 1, 1943, is to be accelerated.

Closing of American Electrified Line.—The Boston, Revere Beach and Lynn Railway, a 3-ft. gauge line which was electrified in 1928, has been closed, and passenger traffic is now being undertaken by buses. The route mileage is about 14 and the track mileage 34, and the electrification is on the 650-volt d.c. system, with overhead current collection.

Soviet Electric Traffic.—According to statistics in the journal *Elektrichestro*, electrically-worked traffic on the U.S.S.R. railways in 1938 amounted to 10,900 million gross *tonne*-km of freight, and 14,335,000 train-km. by multiple-unit trains. The total energy consumption was 429·3 million kWh. A motor-coach is said to average 350 miles a day. In 1938 the route mileage electrified was claimed to be about 1,000.

Remote-Controlled Locomotive.—The Kansas City Power & Light Company has in service for shunting hopper cars to and from a conveyor belt installation a 45-ton two-motor storage battery locomotive which is operated from a controller fixed against the wall of a building in the yard, the driver not travelling on the locomotive. The range of action is 600 ft. from the controller, and speeds up to 12 m.p.h. are possible.

A Rebuilt Suburban Train in New York.—The Long Island Railroad is rebuilding and improving 96 cars of its multiple-unit electric trains in order to make up eight complete trains for use on the 10-cent shuttle service to the New York World Fair during the coming season. This rebuilt stock will supplement another 96 cars which were rebuilt for the same service during 1939, and which have been in normal passenger service during the winter.

Dutch Electrification.—The Arnhem-Nijmegen and Breukelen-Harmelen sections of the Netherlands Railways, totalling 16 route miles, were due to be turned over to electric traction on March 30, and May 19 respectively. The Breukelen-Harmelen spur makes possible direct running between Amsterdam and Gouda via Woerden. One new substation was erected, at Nijmegan. These extensions bring the electrified route length of the Netherlands Railways up to about 328 miles, equivalent to about 17 per cent. of the total route mileage. Five electric locomotives are now under construction for international train working.

Swiss South Eastern Railway.—The electrification of the Swiss South Eastern Railway, described in the issue of this Supplement for March 1, has brought about an amazing transformation of the traffic working. Up the 1 in 20 grades the 960 h.p. motor coaches maintain a steady speed of about 37 m.p.h. when hauling one van, and 34 m.p.h. when hauling three 4-wheeled coaches. The maximum speed on the level is limited to 53 m.p.h. but in service 44-46 m.p.h. seems to be all that is necessary in order to maintain schedules. Descending steeper inclines the speed in general is limited to about 28 m.p.h., being kept to that figure by the electric braking. Coincident with electrification, most of the track was renewed or realigned.

Belgian Electrification.—The Belgian National Railways recently announced that the cost of conversion to 3,000-volt d.c. electric traction of the Brussels-Charleroi line would be 230,000,000 Belgian francs. This figure includes realigning, for speeds up to 75 m.p.h. in place of 62 m.p.h. on certain sections; the four-tracking of the Luttre-Charleroi section; and the elimination of 17 level crossings. Electrification could have been started as soon as agreement had been reached with the Government concerning finance. It was estimated that 44 new vehicles and 23 trailer conversions would be necessary to operate the service, but these would also inter-work between Brussels and Antwerp with the existing two-car and four-car electric trains. The timing for fast trains over the 35 miles between Brussels (Midi) and Charleroi was proposed to be 40 min.

Electric Railway Traction

Contact Line Polarity

THE majority of d.c. electric railways with overhead current collection have contact wire circuits of positive polarity, but here and there may be found a system in which negative polarity is used. Certain effects appear to follow the use of negative polarity, including in certain instances lesser wear on the contact line but greater trouble with insulation. Although some of the trouble may be due to gradation of the insulation, the general effects are electro-chemical in nature and are known as endosmose or electric osmosis, one result of which is a greater tendency to the deposition of moisture round the negative lead. The general effect may be such that it is not practicable to maintain the negative contact wire below earth potential, as the insulators soon become saturated with moisture and thus turn into conductors. A reversal of polarity may be accompanied by a considerable increase in the normal leakage current between the positive and negative conductors, and the insulation between the negative conductor and earth cannot be maintained indefinitely. Other minor effects and requirements as observed on a 1,650-volt d.c. line with overhead current collection are noted in the short article reproduced on page 67 of this issue.

Electrification Summary

APART from subways, lines which have been operated electrically since their inception do not account for more than an insignificant portion of the world's total electrified mileage, practically all of which is composed of conversions from steam-worked lines. The total route mileage of converted steam railways now approximates to 21,000, equivalent to a track mileage of 33,000. For many years a.c. and d.c. systems were each responsible for about half the total, but in the last seven or eight years d.c. has drawn ahead despite such conversions as the Pennsylvania main lines and extensions in Europe and Scandinavia. High-tension developments and rectifier substations have provided a fillip to d.c., but not a little of the preponderance of that system is due to the continuous extensions of the electrified suburban areas of big cities, *e.g.*, London, Paris, Sydney, and on Long Island, for which low-voltage d.c. has always been used, and for new high-tension d.c. suburban lines such as those at Rio and Warsaw. Of the a.c. total of about 9,500 route miles, single-phase traction accounts for 88 per cent. the only three-phase system being in Italy, except for the 13-mile Nacimiento—Gador line in Spain. In America, the single-phase conversions have been carried out at 11-kV 25-cycles, but in Europe a special railway frequency of $16\frac{2}{3}$ cycles has been general, in conjunction with a contact wire voltage of 15 or 16 kV. Something like 3,000 electric locomotives and 15,000 motor-coaches and trailers are used for the operation of the electrified railways (excluding subways) throughout the world, and in output extend up to the 12,000 h.p. locomotive for the Gotthard line of the Swiss Federal Railways, the 10,000 h.p. triple-unit freight locomotives on the Virginian Railway, and the Pennsylvania GG-1 express class with a short-time rating of about 9,000 h.p.

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ELECTRIC RAILWAY TRACTION SUPPLEMENT

This issue of the Electric Railway Traction Supplement is the last that will appear for the duration of the war. Henceforward articles illustrating and describing developments in electric railway traction will appear at four-weekly intervals as a section of THE RAILWAY GAZETTE and not as a separate supplement. An index covering the issues from January 5 to June 21 inclusive is presented this week: in the future, articles on electric traction will not be folioed separately, nor will a separate index be issued in respect of them.

Swiss Electrification

THE extraordinary efficiency and capacity of the electrified sections of the Swiss Federal Railways are very apparent to the traveller in Switzerland. Electrification of the Federal system was begun about 35 years ago, and received a great impetus after the last war. A great deal of experimental work had to be done before conversion became a practical proposition, but, particularly in view of the abundance of water power which could render the railway system almost independent of foreign fuel, certain leading officials were strong in supporting continued conversion, until now approximately 90 per cent. of the traffic is hauled electrically. In the 1939 report of the Swiss Federal Railways the Administrative Board says that it would not have been possible for the Federal Railways to have dealt with the exceptional requirements of traffic during the last eight months, and consequently to achieve the resulting increase in receipts, had not the highly developed electrification of the system enabled the whole traffic to be handled without having to worry about lack and increased cost of fuel. The board felt it a duty to express thanks to the men who, with unfailing energy, had devoted a considerable part of their careers to the electrification of the Federal Railways, undeterred by the many attacks to which they were subjected. Reference was made particularly to Mr. Anton Schrafl, for many years President of the general management, who might contemplate his life-work with legitimate satisfaction, and to three other men, who died last year, and to whom gratitude was due for their efforts on behalf of electrification, namely Federal Councillor Robert Haab, who both in the general management of the Federal Railways and later as Chief of the Federal Department of the Post Office and Railways, placed the whole force of his personality at the service of a cause which he felt from the first to be of paramount importance; Mr. E. Tissot, of Basle, who presided over the commission of enquiry into the question of railway electrification; and finally, Mr. Emile Huber-Stockar, who as Chief Engineer and Technical Adviser to the general management largely contributed to the success of the great electrification undertaking.

THE ECONOMICS OF RAILWAY ELECTRIFICATION

A précis of the factors affecting the cost and efficacy of conversions from steam to electric traction

RAILWAY electrification is now almost wholly governed by financial conditions, and in view of the large capital expenditure involved it is essential that a careful estimate be made of the likely increase in receipts or decrease in working expenditure. If electrification is to be justified financially it is only in these directions that the capital charges can be covered.

Electrification brings with it so many ancillary advantages that it is very difficult to obtain from the financial returns the improvements which may be credited to it. Even in the best example a number of arbitrary assumptions must be made. For a new conversion scheme comparative data can be obtained only from other similarly converted lines, which may differ more or less as regards working conditions. When comparing an electrified service with the previous steam operation allowance should be made for improvements in the latter which might have been carried out if steam traction had not been abolished.

In the case of a new line, although the comparisons between steam and electric operation are both of necessity based upon experience elsewhere, the final comparative values are probably truer than in the electrification of existing steam railways, where many extraneous considerations must be taken into account.

Interest and Capital Charges

Interest, capital repayments, and depreciation charges arising from the initial capital expenditure are always the principal item in the cost sheets of electrified systems. In one particular case 65 per cent. of the annual cost of working the electrified system was due to capital and depreciation charges, actual operating expenses being responsible for only 35 per cent. The corresponding figures for steam traction are something like 15 and 85 per cent. Thus it is easy to see not only the necessity for accurate estimates, but also the vital effect of the rate of interest to be paid on the money required for conversion, and of depreciation.

If money is cheap, an electrification scheme might show a profit where, if a high rate of interest had to be paid, it would be worked at a loss. The economic interest rate varies with different lines; 8 or 9 per cent. might not be too high a price to pay if conditions were exceptionally favourable to electric traction, but many cases exist in which even 3 per cent. would prevent a profit being earned.

Depreciation

Apart from estimating the interest on capital at the actual rate in force at the time of the expenditure, which rate may vary appreciably during the course of a big conversion scheme, accurate figures must be allowed for the depreciation of equipment, rolling stock and permanent way, but comparisons are complicated because of the different accounting methods in force on different railways.

In the specific example mentioned above, in which capital charges amounted to 65 per cent. of the annual expenses, 51 per cent. represented interest on capital and 14 per cent. depreciation. If these figures are considered as more or less average it will be appreciated that an error in the allowance for depreciation is not of such great consequence as is a lack of judgment, or a lack of good fortune, in the problem of interest on capital expenditure, although an error in depreciation may involve the loss of a large sum of money.

Engineering Works

Theoretically, the debit side of an electrification account should contain all the sums spent on the installations directly required by electric traction, the electric rolling stock and engineering works, such as the alterations to stations, bridges, and signalling, and to the removal underground of adjacent telegraph and telephone lines. The costs of such works are often of some magnitude. In one 300-mile single-phase electrification they amounted to 23 per cent. of the total expense of conversion, but 15 per cent. was due to the removal of the communication circuits.

On the credit side of the balance sheet should be shown the capital expenditure obviated through electrification. In the case of a steam railway working well up to its capacity this may be sufficient to throw the balance well on the side of conversion, by eliminating the necessity for doubling the track, or even of constructing another parallel line. A similar state of things exists at a large terminal station which is unable to cope with any further increase of steam-worked traffic. The cost of doubling the line or enlarging the station would naturally be considered as a reduction in the cost of electrification. As regards the terminal station, electrification may lead to a valuable and permanent source of revenue in the form of ground rent for buildings erected above the station, as has been done with the Grand Central station in New York, and many stations belonging to the L.P.T.B.

Rolling Stock Charges

A question upon which there is often much disagreement is to what extent the electrification is to be burdened with charges from rolling stock and equipment made redundant by the introduction of electrification. If the steam locomotives and coaching stock can be used immediately as replacements of obsolete stock on other sections of the railway, then it is not unjust to credit electrification with the actual value of the stock at the time of transfer. The usual procedure is to debit the locomotive renewal fund with at least a portion of the cost of the electric locomotives or rolling stock. With the initiation of a general electrification scheme the provision of steam locomotives ceases to be necessary, and the Weir Report advocated that sums which normally would have been set aside for this purpose would be regarded as a credit against the cost of electric locomotives. Motive power and rolling stock renewal charges are usually met from a separate fund which is built up out of revenue.

If the steam stock must be written off, electrification must bear the charges, but in the case of watering and shed equipment and the like, the interest charges of the invested capital are carried on as before. Nevertheless, it is at least debatable as to whether the outstanding depreciation charges of such equipment due to premature scrapping should be carried by the electrification. In any event, the matter is influenced by the system of accounts. But whatever the credits or debits, either in the capital account or the operating expenses, electrification should

improve the profit and loss account and in any event must not be a charge upon it.

Fuel Problems

One of the principal items in the working expenses is fuel and in this electric traction is generally supposed to show large savings due to the higher all-round efficiency of a big power station. While this may be so, there is some question as to how the comparative costs should be distributed. This is an important factor, whether the railway generates its own current or buys it from a supply authority. Interest on capital invested in a power station is covered in the capital charges instead of in operating expenses, but where energy is bought from a power company the capital charges of the station, the cost of power production and transmission, and the power company's profits are all included in the unit cost of current, and which in the railway accounts would appear as operating expenditure. The distribution of such charges is further affected by the ownership of the transmission lines between the generating station and the substations, and in addition by the type of generating station, *i.e.*, steam, diesel, or hydro-electric.

Probably it is best to consider the cost of coal on the tender of a steam locomotive against the cost of current at the pantographs, as this basis covers the transport and handling cost of locomotive coal as well as the maintenance and operating expenses of substations and contact lines. In early electrifications most railway companies erected their own power plants, but with the increase in general power supply it became more usual, and, indeed, in many cases obligatory, to purchase the energy from a grid. As a rule energy can be purchased as cheaply or more cheaply from a grid, but grid energy costs are tending to rise, and the reliability of such networks does not appear to be all that was claimed a year or two ago.

Reduction in coal consumption is of great importance when the country concerned has little or no coal of its own, especially if it has natural resources in the form of water power. France is a case in point. The old Paris—Orleans Railway, which imported a good deal of its locomotive coal, saved nearly 60,000 tons of coal a year on an electrified route length of 220 miles; these lines were generally level but carried a very dense traffic. With much lighter traffic the Swedish State Railways have saved the import of about 80,000 tons of coal a year in the operation of the 485-mile line between Stockholm, Krylbo and Ånge. Different cases vary over a very wide range, and it is not impossible to get a comparison unfavourable to electric traction between the cost of fuel on the tender and the price of current at the pantographs.

Maintenance of Stock and Track

In practically every application of which there is record, electric locomotives have shown appreciable savings in maintenance costs compared with the steam locomotives they have displaced, even when the mileage and power have been increased due to a rise in traffic. In services worked by locomotives the reduction in certain examples has been 50 per cent. or more, but the use of multiple-unit trains makes a true comparison difficult in suburban work.

It is not invariably that the permanent way requires more frequent renewal when the train service is changed over from steam to electric traction. In Switzerland the track lasts longer under electric services than it did with the displaced steam traffic, but the increase in density has not been great. Exactly the opposite effect is found on such systems as the Southern, and the Metropolitan and District lines of the L.P.T.B. This is due mainly to the tremendous increase in train services provided, and to the generally higher speeds. How much of the extra wear and tear on the track is due to increased frequency and how much to the type of tractive power provided has never been determined. In Switzerland the electric locomotives used have comparatively large-diameter wheels, the bulk of the weight is sprung and the centre of gravity is high; the number of multiple-unit trains in traffic is negligible. The multiple-unit trains operated by the two English systems mentioned above have characteristics the very opposite of these. The wheels are small in diameter, there is a comparatively heavy unsprung weight due to the use of nose-suspended motors with rigid drive, and the centre of gravity is rather low. Furthermore, the presence of a third, and sometimes of a fourth rail, and of cables close to the track, causes more time to be spent in routine track maintenance work than when the current collection is overhead.

If any section of line is operated entirely by electric traction there is a measurable saving in the upkeep of such structures as stations, signal gantries and over-line bridges, and also in the cleaning of the carriage stock, especially if there are many tunnels on the line. These factors may be difficult to evaluate, but they are important and cannot be neglected.

Labour Charges

For equal train services electrification should always bring a reduction in the personnel, due partly to the faster schedules and heavier loads, making possible a reduction in man-hours and partly to the practicability of one-man driving operations. Labour problems have occasionally made the latter a delicate problem, but the increase in train services usually given on electric passenger lines enables most of the running staff to be kept on or transferred to other duties. Unemployment problems or general policy have often been cited to strengthen the case for electrification, but the fact remains that there are many lines to which electric traction could be applied without such excuses, and it is not likely that these reasons will have any great weight in post-war investigations.

Conclusions

Apart from suburban lines, mountain sections, or the existence of a special fuel problem, a low rate of interest on the capital involved, in conjunction with a reasonable power cost, can make electrification a paying proposition on many lines. On the Netherlands Railways extensive electrification was retarded for some years by high power costs; after the price of current was reduced by 30 per cent. the electrified route mileage was almost tripled within six years.

For any set of conditions there is a critical traffic density in ton-miles per annum per route- or track-mile below which conversion will not pay. The easier the gradient profile the higher is the critical density of traffic. Money-raising on easy terms has not always been possible in the past, but the Southern Railway in this country has never appeared to have had any difficulty in raising capital to extend its electrified system to the present remarkable proportions. A method of finance which has been followed once or twice within the last few years is for a large electrical contractor to finance the conversion for which he is building the plant, being paid back in the normal manner over a period of years, or else by agreeing to be repaid from the extra net revenue which electrification brings in its wake. The actual cost of conversion varies enormously according to local conditions and to the system employed. The London—Portsmouth route of the Southern Railway cost about £31,000 a route mile, or £12,000 a track mile, to convert to low-tension d.c., including new and rebuilt rolling stock, signalling, and engineering works.

LATEST BRUSSELS—ANTWERP MULTIPLE-UNIT STOCK

Heavy all-steel two-car trains were built in 1939 to supplement, for stopping trains, the existing four-car sets used in fast traffic

PARTICULARS of the double-suspension bogies used on the eight two-car electric trains built last year for the Brussels—Antwerp stopping services were given in the May 24 issue of this Supplement, but the trains themselves have some interesting features and are good examples of modern high-tension d.c. equipments, albeit somewhat heavy judged by normal standards.

General Particulars

These eight non-articulated trains are each made up of two cars coupled together by a Scharfenberg automatic multi-point coupler and fitted at the outer ends with Henricot automatic couplers and manually-connected jumpers. Two or more of these sets can be coupled together and worked in multiple-unit, or coupled to and worked in similar manner with one of the four-car sets operating the fast services. The new two-car formations were designed to make the 44·5-km. (27·65-mile) run between Brussels (Nord) and Antwerp (Central) in 49 min. inclusive of 14 intermediate stops, and can run at the high (for stopping sets) top speed of 120 km.p.h. (75 m.p.h.).

Although the two pantographs are both mounted on one coach—that without luggage compartment—each vehicle is a motor-coach having one driving and one trailing bogie, the driving bogie being equipped with two springborne motors. The stock was designed, in conjunction with the Belgian National Railways, by the Ateliers Metallurgiques de Nivelles, and was built by that company and by the Ateliers de la Dyle. The empty weight of 104 *tonnes* for a two-car formation given in our issue of May 24 was the estimated weight, and the actual tare is 109·5 *tonnes* (107·8 tons), and the maximum laden weight 129 *tonnes* (127 tons). The respective adhesion weights are 68 *tonnes* (66·9 tons) and 77 *tonnes* (75·8 tons). The pantograph car seats second and third class passengers, and the luggage-compartment car third class only. The total for a two-car set is 30 second class and 113 third class seats arranged as shown in the diagram on this page, and there is accommodation for up to 100 standing passengers.

Car Bodies

The steel bodies were designed to afford a large carrying capacity while facilitating rapid loading and unloading, and to that end the large vestibules are fitted with sliding doors automatically controlled under air pressure, the driver being responsible for the opening and the guard for the closing. The operation of the folding steps is synchronised with that of the doors. A proportion of the windows is of the half-drop type, and ventilation is assisted by Scheppens extractors in the roof. Heating of the saloons, vestibules and driving compartments is by means of 3,000-volt electric radiators located along the walls and under the seats and suitably protected; the heating is regulated automatically by thermostats. No heating is provided for the luggage compartment.

Bogies and Brakes

Independent suspension systems are embodied in the motor bogies, as indicated in the previous article mentioned above, the motors and brake rigging being carried on one frame and the car body on another. The wheels are 1·118 m. (44 in.) in diameter and the maximum axle load is 19·6 *tonnes* (19·3 tons). All the driving axleboxes are fitted with S.K.F. roller bearings, but half of the carrying boxes are of the Isothermos type and half of the Friedmann pattern.

Braking on the automatic self-regulating Westinghouse system is provided. The piston of a supplementary cylinder actuates secondary rigging, the action of which on the main rigging is additional to that of the main cylinder, and results in an aggregate retarding force at top speed equivalent to 160 per cent. of the braked weight. The pressure in the supplementary cylinder depends on the train speed, and is governed by a centrifugal self-regulator driven from one of the axles, and forming a retardation controller. Two blocks a wheel are used.

Electrical Equipment

The monobloc motor-compressor-generator set weighing 860 kg. (1,895 lb.) comprises a 3,000-volt d.c. motor driving an auxiliary generator, and a two-stage reciprocating compressor. The set is suspended at three points on the frame through Silentblocs, and the shaft is common to the three machines, the armatures of the motor and generator being mounted on a loose sleeve. The set works automatically; it can revolve constantly as long as the

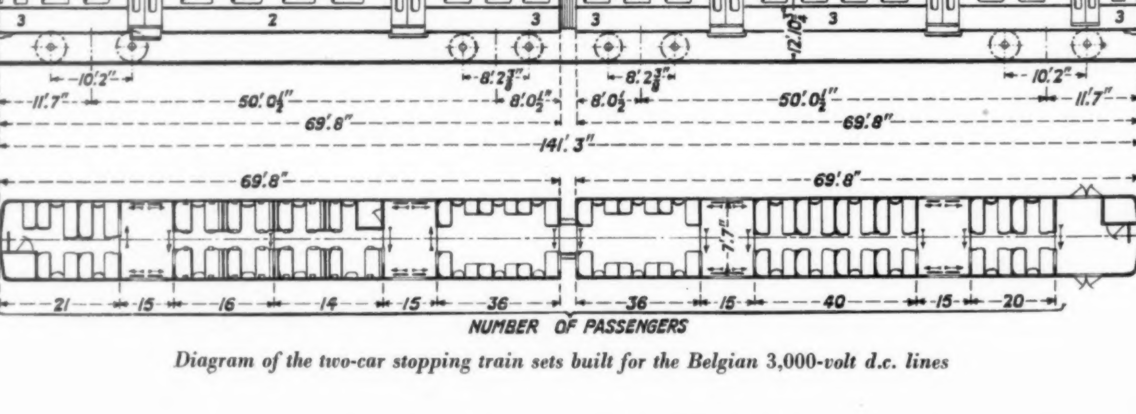


Diagram of the two-car stopping train sets built for the Belgian 3,000-volt d.c. lines

generator or the compressor works under load. When the required pressure in the reservoir is reached, the set continues working if the output of the generator is sufficient. Under such conditions the compressor exhausts to the atmosphere.

Two pantographs and an induction coil are the only parts of the electrical equipment mounted on the roof; most of the apparatus is suspended from the underframes of the vehicles, but some bulky parts are placed in cupboards located at the ends of the coaches. Both pantographs are mounted on the roof of one coach, to avoid multiplying the wiring between the bodies. The collectors have two sliding pieces separated by a groove filled with grease, and they are held in the normal position by means of four springs.

The isolating cock of the air pipe feeding the pantograph servo-motor is provided with a key locking system, and the devices controlling the traction circuits are commanded by the electro-pneumatic process. Current for the auxiliaries is supplied at a voltage of 36 to 45, and the air pressure is 5 kg. per sq. cm. (70 lb. per sq. in.). While starting, the resistors are automatically cut out by a battery of electro-pneumatic contactors governed by a controller which works under the control of an accelerating relay.

Motors

The traction motors are series coupled in pairs; they are of the self-ventilating type with one-piece cast-steel casing and fireproof insulation. The coils of the four main poles are series coupled and put in parallel by a shunting relay. The four motors aggregate 820 h.p. on the one-hour rating and 675 h.p. on the continuous rating. The gear drive operating in conjunction with the Sécheron individual axle drive has a ratio of 1 : 2·87, and the four motors produce at the wheel treads a starting tractive effort of 8,000 kg. (17,640 lb.) and 1,000 kg. (2,200 lb.) at 120 km.p.h. (75 m.p.h.).

The cast-steel armature bearings are of the S.K.F. roller type, designed for grease lubrication. A steel ventilator mounted on the pinion side of the armature sucks the air through the motor by a wide opening at the top of the casing on the commutator side. The air thus aspirated is taken from the roof by Schepens large-capacity intake apparatus; it is rendered dustless by means of Vickers oil filters. The pinions and gear wheels are of nickel-chrome steel, and the wheel is mounted on a cast-steel hub pressed on the hollow-bored shaft. The cast-steel gear case is made in two pieces, the upper half being cast integral with the armature bearing; the gear wheels run in an oil bath. The bearings of the hollow shaft, which are of cast steel and lined with white metal, are in two pieces. They are oil-lubricated by means of a side pad made of wool wicks, the ends of which are immersed in the lubricant. The motor weight is entirely springborne; it amounts to 3½ metric tons per motor.

Cables and Ducts

The cables for the traction circuits, the 3,000-volt circuits for the auxiliaries, and the control circuits are in sheet-metal ducts secured to the coach underframes by means of cast-aluminium straps. Branch boxes, also of cast aluminium, are provided at the points where the cables feeding the motors and other apparatus lead off. These ducts can be inspected by removing the trap covers provided in the central corridor of the coaches. The total weight of the electrical equipment per two-car set is 18·1 *tonnes* (17·8 tons), and the material was supplied by the Ateliers de Constructions Electriques de Charleroi, and the Soc. d'Electricité et de Mécanique de Gand to the requirements of M. Dusquesne, the Electrical Engineer of the Belgian National Railways.

Wear in Overhead Conductor Lines

THE influence of line polarity on the wear of overhead conductor cables of electric railways working with d.c. is the subject of an article by the chief engineer of the Vascongados Railway in a recent issue of *Anales de la Asociacion de Ingenieros del I.C.A.I.*, of Madrid. The Vascongados Railway and a neighbouring line, the Bilbao—Portugalete, both work with positive tension in the conductors, while on another electric railway in the same district, the Bilbao—Las Arenas, the conductor line circuit is of negative polarity. Records showed that the two first-named railways found an average rate of wear on the conductor cable of 1·27 and 1·15 mm. respectively per 100,000 pantograph passages, but on the Bilbao—Las Arenas line, with negatively-charged conductor, the wear was only 0·156 mm. In view of the considerable economic advantage in maintenance costs the Vascongados Company decided to change the polarity of its conductor line, and this was done on February 10, 1936, but on the 26th of the same month, after the first heavy rainstorm, the original polarity had to be restored owing to difficulties with insulation. The conclusions arrived at by the author are that the wear on conductor cable is considerably less with a negative potential in the line, and there is an appreciable saving in maintenance costs. On the other hand, a change of potential on an existing line may reveal weak points in the insulation. Two pantographs may have to be used to collect the same amount of current. It is also necessary to reverse the connections to some of the auxiliary service switches, and the change in the return circuit requires a careful study of local conditions, rail insulation, adjacent cables, pipe lines, etc., particularly where there is constant humidity, *e.g.*, in tunnels.

Italian Substation Plant

OVER 100 rectifiers and half-a-dozen mobile rectifier substations to Brown Boveri designs have now been supplied to the 3,000-volt d.c. system of the Italian State Railways. A number of the rectifiers are operated in substations permitting of regeneration, and the fundamental connections of a plant of this type, at Bologna (S. Viola), were described in the issue of this Supplement for August 23, 1935. A more complicated example is to be found at Cave dei Tirreni, on the Naples—Salerno section, in which the three-phase voltage on the primary side of the plant is 56-64 kV at 42, 45 or 50 cycles and the contact wire tension is 3,000 to 3,400 volts d.c. Of the three 2,000 kW rectifier plants one is reversible and the other two have voltage regulation and short-circuit protection by grid control. Under normal conditions the inverted rectifier and one or two rectifiers are working, according to the load on the d.c. system, but as this particular substation is subject to high peak loads, the reversible rectifier is arranged so that it goes over automatically to a.c.-d.c. working when the other two rectifiers are overloaded. As soon as the d.c. load has fallen again, the reversible rectifier goes back to d.c.-a.c. operation. The change-over of the main current leads of the cathode and transformer neutral point takes place under no current, because the circuit is opened before the change-over is carried out. There are various interlocks to prevent faulty switching. The standard substation on the more level lines, *e.g.*, Milan—Bologna, has two steel-tank rectifiers with an individual continuous rating of 2,000 kW and a momentary overload capacity of 6,000 kW, but in such locations no arrangements are made to feed regenerated current back into the a.c. system.

THE SOROCABANA RAILWAY ELECTRIFICATION PROJECT

A study of the financial, traffic and fuel aspects of a £1,500,000 metre-gauge conversion

By our Brazilian Correspondent

THE increase in the price of coal and the difficulties attached to obtaining adequate supplies as a result of the war have prompted the São Paulo State Government to hasten forward with proposals for the electrification of the Sorocabana Railway, as outlined in the issue of this Supplement for February 2, 1940. The scheme comprises a double line 140 km. (87 miles) long, running *via* Cotia, S. Roque, and Sorocabana to Santo Antonio, and the branch line known as Dez Rios, making a total of 330 km. (205 miles) of track, and would include also the supply of 20 electric locomotives, four suburban multiple-unit trains and three substations. A period of two years would be allowed for the completion of the electrification up to Sorocabana, and a further year for the completion of the work up to Santo Antonio.

Tenders Received

Tenders have been received by the railway as follow: the Electrical Export Corporation de Mineração e Metallurgia no Brazil made an estimate of 6,693,493 dollars, plus 19,744 : 000$ contos of reis local currency, making a total of 152,000 : 000$ contos in local currency. One English company presented two estimates: the first based on the use of steel catenary posts, and totalling £1,216,211 sterling, plus 27,920 : 000$ contos local currency, making a total of 113,000 : 000$ contos local currency; and the other based on the use of reinforced concrete columns, and totalling £1,124,211 sterling plus 27,710 : 000$ contos local currency, making a total of 106,000 : 000$ contos local currency. A second English company estimated the cost of conversion at 118,000 contos or 129,000 contos including 25 locomotives instead of 20. A tender from the Consorcio Italiano de Exportazioni Al'Ester was disqualified on the grounds of non-compliance with certain formalities.

As regards payment, the Electrical Export Corporation (General Electric, U.S.A.) fixed no time limit in its tender, but expressed the desire that the period of payment should not exceed ten years and that the Sorocabana Railway should sign promissory notes and guarantee the discount of same. The first English company agreed to accept payment out of the economy effected by electrification as compared with steam traction, and the second English company requested payment in a period of five years but agreed to define conditions later. All designs and plans accompanying tenders were to be examined within a period of three months, and the successful candidate advised immediately, but up to the moment no details have been fixed. A yearly economy of 12 to 13,000 contos is expected by the Sorocabana Railway from the electrification, but as the price of coal is constantly increasing the economy in practice may reach 20,000 contos a year.

Fuel

The fuel problem on the Sorocabana Railway, due to the ever-increasing traffic, is becoming most acute. In 1937 the amount spent on locomotive fuel was 27,400 contos of reis, which represented 28·2 per cent. of the operating expenses. In 1938 this total increased to 33,000 contos, although the percentage in relation to total operating charges remained approximately the same.

Nevertheless, the financial side of the question is not the most alarming part of the problem, as such expense, although heavy, is the natural consequence of the intensity of traffic which affects the quantitive fuel consumption, while the increased cost of living influences the price. More important is the difficulty attached to obtaining such a large quantity of fuel, of which firewood has proved itself, so far, the most economical. In 1937 the Sorocabana Railway consumed 1,296,000 cu. m. of firewood in addition to 7,200 tons of foreign coal and 4,700 tons of the national coal. In 1938 the consumption increased to 1,580,000 cu. m. of firewood, 60,000 tons of imported coal, and 15,400 tons of national coal. Had it been possible to burn firewood exclusively the consumption would have been 1,880,000 cu. m. in 1937, and 2,137,000 cu. m. in 1938.

Apart from the 5th District (from Bernardino de Campos to Presidente Epitacio) and a few other sections, very little firewood is now available along the main lines, and it has been necessary to build penetrating branch lines, in some cases 23 km. (14½ miles) long, into the forests to obtain the necessary supplies, thus increasing the average length of haul and the cost. At present, eight such branch lines are in use or under construction, and in normal circumstances 25 locomotives and 360 open wagons, or 8 and 24 per cent. of the motive power and rolling stock respectively, are lost to the remunerative transport of the railway.

Foreign Coal

An urgent solution of the fuel problem is therefore necessary, and although such a solution may be found in regard to quantity, in the relative facility in obtaining foreign coal this only aggravates the problem from the economical standpoint. The average price of foreign coal placed on the engine tender in 1938 was 210$000 (milreis) a ton, and the price of firewood in similar circumstances was 12$900 a cu. m. Considering 10 cu. m. of firewood as the economic equivalent of a ton of foreign coal, that is, the thermic equivalent of 8 cu. m. increased by 25 per cent. to allow for greater onus in regard to firewood consumption due to greater immobilisation of the rolling stock and motive power in its transportation, as also the more frequent stops to trains occasioned by refuelling, it is seen that the price of 210$000 for coal compares with 129$000 for firewood, or roughly 63 per cent. more. In other words, if foreign coal had been burnt exclusively on the railway in 1938 fuel costs would have been higher by 12,000 contos.

Wood v. National Coal

The use of national coal, likewise, does not solve the problem; firstly because of the poor results obtained in engines not adapted to its use; secondly due to the limited output of the mines. If the Sorocabana Railway had used nothing but national coal on the basis of one ton equal to 5 cu. m. of firewood, and 600 kg. of foreign coal, it would have consumed 427,000 tons in 1938, or almost one half of Brazil's total production. Finally, the national coal is more costly than firewood. In 1938 the average price of national coal placed on the engine tender was 114$000 a ton or 76 per cent. higher than its equivalent in firewood (5 cu. m.) at 64$500. In regard to firewood,

the railway already has in hand various afforestation schemes, but these impose delay on the solution of the difficulties and are of problematical result.

Fuel for Main-Line Section

The obvious remedy seems to be electrification, which from the economical standpoint may be examined for the section from São Paulo to Santo Antonio, where traffic is most dense and where firewood is obtained with greatest difficulty.

The average price of fuel in 1938 placed on the engine tender was 210$000 a ton for foreign coal and 12$900 a cu. m. for firewood. It has not been customary to calculate the cost of firewood on individual sections but it is safe to presume that if the cost of coal on this section equals that of the average for the whole railway, the price of firewood must be 1$000 more a cu. m., making it 13$900.

On account of the passenger trains and the difficulty of obtaining firewood, fuel consumption on this section is divided in the proportions of 65 per cent. of firewood to 35 per cent. of coal. Considering the equivalence of 10 cu. m. of firewood to one ton of foreign coal, and taking into consideration the respective prices and the coefficients given above, the average price of fuel on the São Paulo—Santo Antonio section is:

$$\begin{aligned} 139 \times 0{\cdot}65 &= 90{\cdot}35 \text{ reis} \\ 210 \times 0{\cdot}35 &= 73{\cdot}50 \text{ reis} \\ \hline &\quad 163{\cdot}85 \text{ reis} \end{aligned}$$

or approximately 165 reis a kg. As the minimum specific fuel consumption per ton-km. of gross weight transported so far recorded is 0·090 kg. it may be concluded that the fuel cost of hauling a ton-km. of gross weight is $0{\cdot}090 \times 165 = 14{\cdot}85$ reis.

In the case of electrical energy, considering 1 kWh equal to 2 kg. of coal, and the kWh cost 80 reis, the cost of electricity to haul the same ton-km. of gross weight would be:

$$\frac{80 \text{ reis} \times 0{\cdot}090}{2} = 3{\cdot}60 \text{ reis}$$

or a fuel economy of $14{\cdot}85 - 3{\cdot}6 = 11{\cdot}25$ reis per ton-km. To obtain the total annual fuel economy over the whole section it only remains to multiply this unit economy by the total number of ton-km. hauled in both directions, and with this total reaching 700 million ton-km. in 1938 the result would be:

$11{\cdot}25 \times 700{,}000{,}000 = 7{,}875:000\$000$ (contos of reis).

As a result of electrification, however, further economies would be effected which would allow the total economy to be valued at 1·3 of the above total (or 10,237 : 500$) for the São Paulo—Santo Antonio section. It is this amount which must be considered as available for interest on, and amortisation of, the capital involved, and the convenience or otherwise of electrification may be given by the expression

$$A < E_T$$

in which A is the yearly amount for interest and amortisation of the capital involved, and E_T is the total economy effected by conversion.

Rolling Stock

From information already supplied to the railway by interested contracting firms the cost of electrification of the São Paulo—Santo Antonio section (140 km. or 87 miles of double track) would be 100,000 contos including transmission lines, distributing system, substations, and traction material. The last item generally represents a third of the total cost (33,400 contos in the present case), though its financial aspect is somewhat different from the others if it represents only the purchase of new tractive units. In a truthful economic comparison between electric and steam traction such a total or part of it would probably be excluded and considered as a common case of new locomotive acquisition made periodically by the railway to cope with its ever-increasing traffic.

Considering a capital of 66,600 contos only, a period of amortisation of 25 years (average duration of installations) and yearly interest at 10 per cent. (8 per cent. interest and 2 per cent. for renewals and conservation), the annual charges corresponding to capital outlay would be $0{\cdot}110 \times 66{,}600$ contos $= 7{,}326$ contos, which is much less than the savings in operating charges, and gives a net annual profit of 10,237 : 5 contos − 7,326 contos = 2,911 : 5 contos.

Displaced Steam Locomotives

If the economical aspect of the problem is incisive, the financial aspect is more delicate. In the first place, although it would mean a temporary surplus of probably 50 steam locomotives, the capital which would have to be applied is really 100,000 contos, including the cost of electric locomotives which would have to be acquired immediately and not in instalments when necessity arose, as in the case of steam locomotives. Furthermore, if the railway or the State Government of São Paulo have not the funds necessary for so great an undertaking, the financing by interested contracting firms would be a solution, and some have already shown a certain willingness in this direction, but in this case the period of amortisation already mentioned, based on the duration of the installations, would be too long, and it is possible that the period stipulated would be shorter, probably 15 years, but with a relative compensation in the rate of interest to 6 per cent. For a term of 15 years at 6 per cent., plus 2 per cent. for renewals and conservation, the annuity corresponding to a capital outlay of 100,000 contos would be $0{\cdot}116 \times 100{,}000$ contos $= 11{,}600$ contos, exceeding the total economy (10,237 : 500$) by 1,363 : 500$ a year.

Locomotive Hire

To counterbalance this apparent initial deficit the following must be considered:

(*a*) . . . The electrification would allow of an immediate surplus of 50 steam locomotives, the majority of which are of the Mikado type and fairly new, having been purchased since 1924. These have been given a residual value of 400 contos each, making the total value 20,000 contos. Deducting this amount from the capital cost of electrification gives an outlay of 80,000 contos, on which the annual payments would fall to $0{\cdot}116 \times 80{,}000$ contos $= 9{,}280$ contos. This sum is less than the economy effected by the electrification and some of the surplus locomotives could be used on other sections of the railway to cope with increasing traffic. If they were not all absorbed in the first few years, it would not be difficult to rent them to neighbouring railways such as the São Paulo—Rio Grande, North Western, Mogyana, and Viãcao Ferrea do Rio Grande do Sul, which are constantly in need. In 1938 alone, the São Paulo—Rio Grande Railway asked for the loan of 10 locomotives. At the already established yearly rental of 30 contos for each locomotive the 50 available would produce 1,500 contos, sufficient to cover the deficit. Under such circumstances these locomotives alone, either by their capital value or by rental would turn the economical comparison favourably towards electrification.

(*b*) . . . The economy in fuel has so far been based on 1938 traffic, without provision for the future, though the history of the Sorocabana shows that except for one or

two abnormal periods increases have been consistent, as shown by the following table of gross weight ton-km. transported over the whole railway:

Year.	Ton-km.	Index No.
1928	1,669 millions	100
1929	1,773 ,,	106
1930	1,534 ,,	92
1931	1,631 ,,	97
1932	1,547 ,,	94
1933	1,823 ,,	109
1934	2,001 ,,	120
1935	2,320 ,,	139
1936	2,554 ,,	153
1937	2,680 ,,	160
1938	2,814 ,,	168

The total in 11 years has risen 68 per cent., or an average yearly increase of 6·2 per cent., notwithstanding the economical crisis of 1929 and two periods of civil revolution in 1930 and 1932 which caused a serious drop in traffic. Assuming an increase of 5 per cent. per annum for the next few years, traffic on the section under review should reach the following totals:

1940	770 million ton-km.
1941	805 ,, ,,
1942	840 ,, ,,
1943	875 ,, ,,

and the total economy, proportionate to the traffic hauled would be:

1940	11,261 : 250$000
1941	11,773 : 125$000
1942	12,285 : 000$000
1943	12,796 : 875$000

In two years, which is the time the electrification would take to complete, the deficit would be covered by the increase in traffic alone.

(*c*) . . . Even if the yearly deficit of 1,363 : 500$ continued for 15 years, and only thereafter the amortisation of capital began, the net economy of 10,237 contos a year would very soon liquidate the accumulated deficits.

(*d*) . . . It must also be borne in mind that if the cost of fuel increased, the results shown by the electrification would be more favourable year by year. In the last ten years, as an example, the cost of foreign coal has increased 87 per cent. and that of firewood 25 per cent.

Energy Cost and Capital Charges

The only factor which could upset the optimistic conclusions arrived at and create an unfavourable outlook for the electrification would be a disproportionate increase in the price of energy and in the annual charges corresponding to capital outlay. There is not much likelihood of an increase in the cost of energy, and the railway might safeguard itself either by a long-period contract of supply or by building its own power station. The annual charges on capital could only increase if the latter were raised abroad in foreign currency and became subject to an unfavourable oscillation in exchange, as has happened in relation to sterling, which has gone up 94 per cent. from 1928 to 1937, despite the abolition of the gold standard in England in 1931. If the government wished to avoid such a possibility, should prospective contractors propose to finance the undertaking in foreign currency, it would be easy to obtain the necessary capital by an internal loan issue, as was done in the case of the Mayrink—Santos extension, when the amount necessary was quickly subscribed. Under these circumstances the rate of interest would have to be higher, say 7 per cent., but the period of amortisation could be extended to 25 years, equivalent to the duration of the installations.

Conclusions

From the foregoing, the following conclusions may be drawn:

(1) . . . The electrification of the Sorocabana Railway between São Paulo and Santo Antonio is not only opportune but is an urgent and absolute necessity.

(2) . . . The cost can be defrayed by the economy resulting from electrification as compared with steam traction.

(3) . . . The necessary capital, approximately 100,000 contos, can be obtained either by:—(*a*) contracting firms financing the undertaking, and the railway taking the risk of a varying exchange, or (*b*) by an internal loan which would make the question of interest and amortisation independent of an oscillating exchange.

Electrical Pot-Pourri

The St. Gall-Gais-Appenzell Railway, with mixed rack and adhesion services, was converted from steam to 1,500-volt d.c. electric traction in 1931, and is worked by about half-a-dozen double-bogie motor-coaches with individual one-hour ratings of 570 h.p. at 11 m.p.h. and a rail tractive effort of 19,000 lb. The tare weight is about 39 tons, of which the electrical equipment accounts for just over 8½ tons. The drive to each bogie is from a series motor carried on the car underframe and both adhesion wheels and the rack wheels are driven through a slip coupling, cardan shafts, and bevel and spur gears.

* * * *

The Northern of Spain Railway now operates 386 route km. (240 miles) of electrified line, as follows: Busdongo—Ujo (Pajares incline), 62 km.; Manresa—Barcelona, 65 km.; Moncada bifurcacion—San Juan, 106 km.; Ripoll—Puigcerdá, 49 km.; and Alsasua—Irun, 104 km. The electrification of the loop section between Madrid, Avila and Segovia, 187 km. (116 miles), suspended during the civil war, is now being completed.

* * * *

The two most modern American express electric locomotive classes—the Pennsylvania GG-1 2-Co + Co-2 and N.Y.N.H.& H. 0361 type of the same wheel arrangement—have respective weights per continuous h.p. of 98 and 120 lb. In each case the line current is 11-kV 25-cycle single-phase. The Pennsylvania locomotive has a continuous rating of 4,620 h.p. at 54 m.p.h. on a weight of 203 long tons, of which 136½ long tons are available for adhesion. The New York, New Haven & Hartford locomotives are rated at 3,600 h.p. at 55·8 m.p.h. on a total weight of 193 long tons, of which 121 long tons are on the driving wheels.

* * * *

The Sassi-Superga mountain railway near Turin was worked originally on the Agudio combined rack and cable system, but was converted in 1935 to an electric railway of the Strub type, and is now operated by double-bogie and four-wheel motor-coaches taring 26 and 16½ tons, and carrying 70 and 40 passengers respectively. The bigger coaches can haul two trailers, and the gross weight of the whole train is then about 58 tons. The steepest grade is 1 in 4·9, the top speed 8¼ m.p.h., and the electrification system 600 volts d.c. A double-bogie motor-coach has four series motors, each of 103 h.p. one-hour at 6·4 m.p.h. with a conductor rail voltage of 550.

* * * *

Experience on the Birseck Railway, near Basle, has shown that interference with wireless sets has been caused by the copper or aluminium strips of the bow collectors sliding on the copper contact wire, and that the troubles could be eliminated by using carbon contact strips, which give rise to very few high-frequency perturbation voltages. But on the Birseck line when the change-over was made to carbon strips the bow collectors were replaced by light pantographs, which are more satisfactory collectors.

Diesel Railway Traction

Railcar Fires

SINCE we dealt last with the subject of railcar fires (in the issue of this Supplement for June 9, 1939), several other examples have come to our notice, some of which bear out our contentions that although quite a large proportion of railcar fires originate in the auxiliary electrical equipment, the best method of preventing fires or limiting any which do begin, is to insist upon strict cleanliness of the car interior and exterior, including the engine room. Recognition of this factor seems to be gaining ground; as an instance, the engine rooms of the very large diesel-electric locomotives operating the New York—Florida trains of the Seaboard Air Line are vacuum-cleaned every round trip, particular attention being paid to crevices and corners where oil or oily waste might gather. The fire which last year gutted one of the then new Belgian triple-car diesel-hydraulic trains apparently was caused by an initial fire in the exhaust system. During last summer two welded-steel 130 b.h.p. diesel railcars belonging to the Kole Dojazdowe Warszawskie, a private line in Poland, collided, and a fire broke out. As far as can be ascertained, the fire originated in a short circuit in the electric lighting system caused by the collision. In the excitement after the accident and the concentration on getting the dead and injured out of the wrecked cars, the beginning of the fire was unnoticed, and the conflagration soon got beyond the control of the railcar fire extinguishers. A fire resulting from sheer carelessness occurred on one of the bogie cars on the B.A.G.S. Railway. The driver of three cars operating in multiple-unit persisted in putting full torque through all transmissions, although one of the cars was actually in reverse, with the result that the oil in the fluid coupling caught fire, and according to some accounts a minor explosion occurred. The blaze was extinguished by the local fire brigade, but not before the car had been badly damaged. The latest cars of this general type incorporate an improvement in that to drive the brake compressor it is not necessary to run the engine up to a comparatively high rotational speed, and thus the driver is not liable to put an appreciable torque through the fluid coupling and heat up the oil unduly.

In the type of fire caused by a match or cigarette end, lighting first a small accumulation of rubbish or oil-impregnated boards, there seem to be two stages. In the first there is a smouldering fire which if not detected within a short space of time produces a large amount of smoke that may prevent the seat of the fire being identified or reached. Moreover, it leads to a danger of asphyxiation, and the endeavours of the personnel and passengers to avoid this may give time for the development of the second stage of the fire, a rapid bursting into flame of any inflammable parts near the seat of the fire; in a surprisingly short time after this the car may be ablaze from end to end, even if the framework is of steel. The risk of such fires spreading quickly in a diesel car is greatly enhanced if strict attention is not paid to cleanliness and the elimination or close confinement of oil leakage. It is not merely the fuel and lubricating oil in the engine room on which an eye must be kept; leakage from fluid couplings or hydraulic torque converters must be prevented, for it is quite possible for a fire to begin with hot oil on the underframes or underside of the floor, a risk which is obviously greater if the engines are slung beneath the car floor. It is to cover this risk that the French National Railways wash the bogies and underframe gear with hot water pressure jets every 10 to 14 days, a practice which should be extended, and supplemented by frequent vacuum or conscientious manual cleaning of the whole of the car interior.

Alternative Fuels

THERE is no question of the present forms of producer-gas railcars being able to approach the performance of diesel cars or even that of petrol vehicles. The use of such fuel has always followed a defect in the economic system which prevented the adoption of the best, so that a home-produced fuel had to be used. Up to six months ago the number of producer-gas railcars was few indeed. There were handfuls in Germany, Poland, and one or two of the Baltic States. Experiments had been made in France with charcoal-burning cars over two or three years, with the result that the French National Railways had decided to give up further construction, as this form of motive power was so inferior to the modern diesel. Since the war began many belligerent and neutral countries have found it expedient to investigate alternative fuels for their diesel and petrol railcars and small locomotives. Producer gas, derived from wood, charcoal, or a mineral fuel, is the most obvious second choice, but in countries such as Italy, which have almost no natural fuel at all, a somewhat wider research has been made, and at the moment methane is occupying a leading place in the publicity given to alternative fuels for traction and transport purposes. Trials are being made over the Nord Milan Railway with a railcar converted to methane-gas fuel, and only one replenishment a working day is said to be necessary. Other Italian efforts are being directed to the production of motor spirit from sorgo grass, and to the use of hydrogen produced from water by electrolysis. Butane and butane-propane, by-products of processing petroleum and lignite, have been used extensively for high-speed transport engines on the Continent and in America, and in the United States for shunting locomotives also. Another alternative is vegetable oils, to the use of which we gave attention in this Supplement as long ago as August 11, 1933, but certain kinds require the engine to be started on diesel oil or the fuel to be preheated. All these substitute fuels require major or minor modifications to the engine, and many of them give appreciably less power for a given cylinder capacity and speed. Only in the case of producer gas is there likely to be any reduction in the railcar seating capacity, and this should not be more than 8 to 10 per cent.

LONG-DISTANCE DIESEL WORKING IN THE U.S.A.

Operation and maintenance of Pullman and ordinary trains running between New York and Florida coast resorts, and which are diesel-hauled for more than 1,100 miles each way, were described by Mr. E. H. Roy, Superintendent of Motive Power, Seaboard Air Line, in a paper to the New England Railroad Club

The diesel locomotive unit on the Seaboard Line runs on two six-wheel trucks and is powered by two 1,000 b.h.p. General Motors two-stroke engines, with a 600 b.h.p. engine of the same make for the auxiliaries. One unit weighs about 132 Engl. tons. On the 13- to 16-car de luxe Orange Blossom Special, with a gross trailing load of 700 to 875 Engl. tons, three units are used at the head of the train. On the seven- to nine-car Silver Meteor, weighing 350 to 450 Engl. tons trailing and carrying 280 to 360 coach passengers, only one locomotive unit is necessary. In each case the running average over the 1,100 odd miles of the diesel-hauled portion of the run is in excess of 55 m.p.h. Notes on these two trains will be found in the issue of this Supplement for March 17, 1939.

AT the end of 1938 the Seaboard Air Line began diesel operation on the winter-only Orange Blossom Special train providing a through service between New York and Miami, Florida. Between New York and Washington the train is handled by the electric locomotives of the Pennsylvania Railroad, but over the 1,145 miles between Washington and Miami one triple-unit diesel locomotive is used. The Orange Blossom leaves Washington at 6.10 p.m. and reaches Miami at 3.40 p.m. the next day, and this schedule gives a lie-over of seven hours at Washington and 20½ hours at Miami. This turn round at Miami gives sufficient time for maintenance work to permit of the locomotives giving about 100 per cent. availability, and the maintenance is carried out at the Hialeah depot, 3½ miles out of Miami. Originally the Orange Blossom Special was a 12-car steam-hauled train, and the diesel formation was at first 13 cars, but has since been increased to 15 and 16 cars.

Leaving Washington at 6.10 p.m. the southbound train travels over the tracks of the Richmond, Fredericksburg & Potomac Railroad as far as Richmond, Va., a distance of 116 miles, where the crews are changed and the train passes on to the main line of the Seaboard system. Shortly after midnight the train reaches Hamlet, the first service stop, and 370 miles from Washington, and here the locomotive is fuelled and watered from overhead tanks, and the train is replenished with ice and water. The water taken on the locomotive is for the steam-heating system of the train, and the whole train is re-supplied within a stopping time of 10 min. The next service stop is at Wildwood, Fla., 496 miles from Hamlet, and is reached just before noon. The same replenishing is carried out here as at Hamlet.

Round-Trip Maintenance

On arrival at Miami the train is taken to the depot at Hialeah for inspection and regular routine maintenance. The equipment is first placed on the coach cleaning tracks and the locomotive unit is moved to an electrically-lighted inspection pit of a length sufficient to accommodate the three power units. The first operation on the locomotives is to vacuum-clean the interiors, especially round the engines; all crevices and cracks where dust or dirt might lodge are given thorough attention. Experience has shown that cleanliness of the locomotive interior is a most important factor in satisfactory operation.

While the interior is being cleaned, the exterior and under-floor portions are inspected, and the traction motor brushes and commutators examined for wear, and other parts checked and lubricated with grease or oil. The draw gear is examined, the air brake piston travel adjusted as required, and the train control and brake equipment tested. After the engine rooms have been cleaned, the condition of the generator brushes and commutators, relays, contactors, fans and fan belts are checked and cleaning and lubrication carried out as necessary. The crankcase inspection covers are removed from the engines to enable a sight to be gained of the pistons and rings, connecting rods, and bearings. Samples of oil are taken from the engine and checked for cleanliness and quality. The filters for the air, fuel, and lubricating oil are removed, cleaned, and replaced, and attention and testing is also given to the plant for generating the steam for the train-heating system.

Shop Equipment

To facilitate wheel and traction motor changes a horseshoe-type drop table has been installed at one end of the inspection pit, and by its use either one pair of wheels or a complete six-wheel truck can be dropped. The locomotive repair shop, store, and oil room are housed in a building 150 ft. long by 20 ft. wide, located close to and parallel with the inspection pit, and partitioned off into separate departments. The shop is equipped with a small drill press, valve grinder and combination emery and buffing wheel stand, all electrically driven; a 40-ton hand-operated press; and an assortment of small specialised hand tools. The oil room contains small rotary pumps for handling clean lubricating oil from the storage tank outside the building direct to the locomotive tanks, and for emptying the dirty oil tank underground and into which is drained direct the used oil from the locomotives every time a change is made. This room also contains an oil purifier with a capacity of a gallon a minute, and from which large savings in lubricating oil costs are being obtained.

Return Trip and Crew Changes

After being serviced and reconditioned, the locomotive and train leave Miami the next day at 1.20 p.m. for the northbound trip. The first service stop is at Wildwood, 279 miles out, and after 558 miles have been run since last fuelling. Fuel and water are taken on here, and at the next service stop, at Hamlet, fuel, water and ice are taken on board. The train is due at Washington at 11.0 a.m. the following morning, and here the diesel locomotive is taken off and run to the shed of the Wash-

ington Terminal Company for inspection. No routine maintenance work is undertaken here.

Engine crews are changed at Richmond, Va.; Raleigh, N.C.; Columbia, S.C.; West Savannah, Ga.; and Baldwin, Fla., in both directions, and at these points there are emergency water stations for use in very cold weather. A diesel locomotive attendant, selected from the shopmen and given special training, is on duty in the three engine rooms of the 7,800 b.h.p. triple-unit locomotive, and is able to detect and rectify any unusual conditions. A small assortment of spare parts is carried, and if necessary pistons and liners can be renewed *en route*, thus greatly contributing to the satisfactory road performance.

Summer Workings

At the close of the winter season of 1938-39, on April 16 last, the diesel locomotives were transferred to the Southern States Special, and portions of the runs of the Cotton States Special and Robert E. Lee trains, replacing has been running as a separate train to St. Petersburg, Fla., instead of dividing from the main train at Wildwood as previously. This train is a 12-car formation and is hauled by two locomotive units with an aggregate output of 5,200 b.h.p. On the Miami train, with 16 cars, and a triple-unit 7,800 b.h.p. locomotive, the fuel consumption is approximately four U.S. gal. per train-mile and 17·6 miles per U.S. gal. of lubricating oil, but this does not form a very great proportion of the total operating expenses.

Diesel Trains with Ordinary Accommodation

The above trains are made up of normal American Pullman accommodation, but in February, 1939, the Seaboard began operation of the Silver Meteor, a seven-car stainless steel *de luxe* coach train. At first this train ran every third day from New York to Miami and St. Petersburg, splitting at Wildwood. The motive power between Washington and the Florida coast at Miami is a single-

The Seaboard Air Line's Orange Blossom Special on its inaugural diesel-hauled run between Washington and Florida. It is hauled by a triple-unit diesel-electric locomotive with a total installed engine capacity of 7,800 b.h.p.

steam power. The lie-over at the northern end was changed from Washington to Richmond, and these schedules remained in force until December 15 last, when working on the Orange Blossom Special was renewed. As far as the locomotives are concerned, the Southern States Special originates at Miami, and two diesel locomotive units are used at the head of this train to Richmond. A lie-over of 9½ hr. at Richmond is available for any work which may be necessary before the locomotive is despatched on the south-bound Southern States Special as far as Hamlet, where it is detached and placed on the Cotton States Special for Atlanta, Ga. The lie-over at Atlanta is 6 hr. 50 min., after which the locomotive is attached to the Robert E. Lee train back to Hamlet, and there placed on the south-bound Southern States Special for Miami.

Experience with diesel locomotives on the Seaboard was such that an order for a further nine 2,000 b.h.p. locomotive units was placed in 1939, and the use of this motive power has now been extended to the West Coast Orange Blossom Special, which during the present winter unit 2,600 b.h.p. locomotive (2,000 b.h.p. main traction equipment), but the run of the detached portion between Wildwood and St. Petersburg is in the hands of a 600 b.h.p. diesel locomotive. At the beginning of December the train formation was increased by two cars and the run between New York and Florida made a daily one in each direction. Every third day a similar train is run in each direction between New York and St. Petersburg, the motive power between New York and Washington, like that of the other trains, being a Pennsylvania electric locomotive. The schedule is 25 hr. between New York and Miami and 24 hr. on the St. Petersburg trip. When running with a single 2,600 b.h.p. locomotive and seven-car train on a schedule of 26½ hr. south-bound and 27 hr. north-bound on the Miami service, the fuel consumption was about 1·3 U.S. gal. per train-mile and the lubricating oil consumption 54·7 miles per U.S. gal.

In the study of diesel train operation made by the Seaboard officers it was found that, even when the overall speeds were not accelerated, traffic increased when diesel locomotives were used. The Seaboard believed it could

reduce the running time between Richmond and Miami by about three hours, and between Miami and Richmond by approximately four hours by the use of diesels, and with new schedules and equipment and an increase of two cars a train compared with steam haulage, new business was naturally anticipated. An analysis of the 1938-39 winter season of the Orange Blossom Special showed an increase of 64 per cent. in the number of passengers carried, and the operating costs were substantially reduced. The popularity and efficient operation of the diesels seems to be due mainly to the safer operation consequent upon the better vision and easy access to all controls in the driver's cab; the smoother handling, particularly at starting and on grades; the higher speeds uphill making unnecessary very high maximum speeds downhill; and the cleanliness resulting from the elimination of smoke, soot, steam, and cinders.

At the time the Seaboard equipment was first ordered, the locomotive builder, the Electro-Motive Corporation, was just changing its main-line diesel model by the increase in the individual engine output from 900 to 1,000 b.h.p., and by the introduction of a simpler and more efficacious electric transmission. Minor troubles were therefore anticipated, but were quickly put right at the expense of the builder, several men being sent to observe the behaviour of the nine 2,600 b.h.p. locomotive units first supplied. Prior to the delivery of the equipment, eight of the Seaboard shop workers were sent to the builder's training school, and having since worked with the builder's temporary service men in addition, are qualified to cope with any problems which arise in operation, and maintenance costs are being reduced.

Mileage and Costs

In the first year of service approximately 2,000,000 train miles were handled by the diesels, and the first single 2,600 b.h.p. unit brought into traffic on the Silver Meteor in February, 1939, covered 185,000 miles up to September 1 of the same year, and in that period was out of service for only ten days. Over the first nine months of service on the Orange Blossom, Southern States, Cotton States and Robert E. Lee trains, the maintenance and repair costs were about 6 cents a mile and the running costs 8·3 cents a mile, giving a total operating cost exclusive of financial charges of 14·3 cents a mile. Average speeds between Richmond and Florida are 55 to 57 m.p.h., and the maximum speeds are of the order of 80 m.p.h. With the 16-car trains on the Orange Blossom during this winter, two pull-ups are necessary at some of the stations, but the locomotives still have a power reserve on present schedules.

* * * *

In the discussion on Mr. Roy's paper, Mr. E. K. Bloss, of the Boston & Maine Railroad, said the diesel-electric lent itself beautifully to switching, though in switching service it was a wheelbarrow—there was no glamour, no romance, and one had a fine time trying to get the tools and parts which Mr. Roy had said were necessary. If switchers could be painted bright orange and lavender, and stretched out to 6,000 h.p., then some of the things wanted could be obtained. When they were put in a freight yard they were just another thing out in the freight yard, and to be really useful one had to be able to fix them with a piece of bailing wire and an alligator wrench. In regard to main-line locomotives costing a lot of money, they had to be used most of the time in order to be justified economically.

Mr. K. Cartwright, of the New York, New Haven & Hartford Railroad, said his road had only one diesel train, the 800 b.h.p. Comet. They had some new steam locomotives of 3,800 nominal h.p., which were making a mileage closely comparable with that of the Comet. In the first year of its operation the Comet ran 133,000 miles and the maintenance cost of power plant and motor trucks was 9·5 cents a mile; the first year's operation of the steam locomotives showed a maintenance cost of 8·0 cents a mile. In the second year of the Comet's operation, when it ran 130,000 miles, the maintenance cost was 11·1 cents a mile, and that of the steam locomotive was 9·4 cents. In the third year of operation the Comet ran 135,000 miles and the maintenance cost was 12·7 cents a mile compared with a steam locomotive maintenance cost of about 11·8 cents a mile.

Danish Activities

The Danish State Railways are to take delivery of a further nine standard diesel-electric railcars of Class MO; they will then possess 49 railcars of this general type. Construction is to begin shortly of an experimental twin railcar, which will be powered by two pressure-charged diesel engines of 500 b.h.p. each; the transmission is to be electric, as on all other diesel stock on the State Railways except shunting tractors. The new twin unit will have 117 general-class seats and is to be capable of hauling up to six standard passenger coaches, thus giving a train with acceleration and speed equivalent to that of the short diesel trains which have come into such prominence lately, but with a seating capacity of 600. In short, the new unit will correspond to two standard railcars worked in multiple-unit, but it will weigh less and have greater seating capacity.

As from December 10, the evening Lyntog in both directions are no longer transferred across the Great Belt, and passengers have to change from train to ferry and *vice versa*. Arrangements have been made so that the trains on both sides of the Belt are of identical type, so that passengers can retain their seat numbers. The morning Lyntog in both directions are still being transferred. The timings remain unchanged in spite of the delay caused by the double transfer of passengers, and time-keeping is made still more difficult by the introduction of conditional stops at Sorø and Ringsted for the Vesterhavet Lyntog towards Copenhagen without increase of journey time. A curious consequence of this arrangement is that the present reduced timetable shows a new fastest run in Denmark, *viz.*, 9 miles in 7½ min. between two conditional stops (So-ø to Ringsted), corresponding to 72·0 m.p.h. against the hitherto fastest run of 38·3 miles in 35 min., equivalent to 65·7 m.p.h.

American News.—The Colorado & Southern Railroad and its subsidiary the Fort Worth & Denver City, have applied for a loan of $1,300,000 to buy two new stainless steel diesel trains, offers of which have been received from the Electro-Motive Corporation for two locomotives at $376,000, and from the E. G. Budd Manufacturing Company for two four-car trains at $304,500 each. The Chicago, Rock Island & Pacific has ordered five 360 b.h.p. Davenport-Besler and five 360 b.h.p. Whitcomb diesel-electric locomotives; the Central of Georgia one 600 b.h.p. Electro Motive diesel locomotive; the Tennessee Central one 660 b.h.p. Alco diesel locomotive; and the Panama Railroad five double-bogie General Electric diesel-electric locomotives. The Baldwin Locomotive Works is completing 28 diesel-electric locomotives of 660 and 1,000 b.h.p. Some of these are for stock, but several of the 1,000 b.h.p. type have been delivered to the Missouri Pacific and A.T.S.F. lines.

RAILCARS IN THE BALTIC STATES

A short review of the four-wheel and eight-wheel cars operating local and semi-fast traffic in Sweden and the countries along the eastern shore of the Baltic Sea

IN the countries flanking the Baltic Sea, railcar traction has been applied to a variety of services, but except in Germany has not attained to any great magnitude, although as a proportion of the motive power ordered within the last three or four years railcars are predominant. In Sweden petrol railcars of a light type are at least as numerous as diesel patterns, but in Finland, Estonia, Lithuania and Latvia the railcar stock is made up principally of oil-engined vehicles supplemented by a few wood-burning producer-gas cars.

Finland

Normal railcar services are operated by the State Railways over a route mileage approximating to 1,150, as indicated on the accompanying map. Railcars were introduced in 1928, and of the score of vehicles now in traffic all except two are diesels. The early diesel cars had electric transmission and 90 b.h.p. Atlas diesel engines. Succeeding cars had increased engine power—from 150 to 240 b.h.p.—operating in conjunction with electric transmission of the Lemp or Ward-Leonard types. Since 1934 all new cars have been equipped with mechanical transmission; recent vehicles have engines and mechanical transmissions built under licence by the Finnish firm of Tampella, but ever since 1928 the mechanical portions of the railcars have been constructed at the shops of the State Railways. All the diesel cars are of the double-bogie type and all have wooden body lagging and insulation; in general they have been built with a maximum axle load of 13 *tonnes,* have only third class seats and a luggage compartment, and all bogie cars are used for trailer haulage.

The newest cars have a six-cylinder Tampella-M.A.N. engine giving a maximum of 240 b.h.p. at 1,000 r.p.m. and mounted on one bogie. Two axles of this bogie are driven by Tampella-T.A.G. transmission, and give the car a top speed of 90 km.p.h. (56 m.p.h.). A total of 64 third class seats and about 70 sq. ft. of luggage space are provided on a tare weight of 38 *tonnes* and within a body length of 62 ft. The driving wheels are 960 mm. (37·8 in.) in diameter and are spread over a bogie wheelbase of 3·8 m. (12 ft. 6 in.); the maximum axle load is 13 *tonnes,* and S.K.F. roller-bearing axleboxes are used throughout. The two bogies are pitched at 12·55 m. (41 ft. 1 in.) centres.

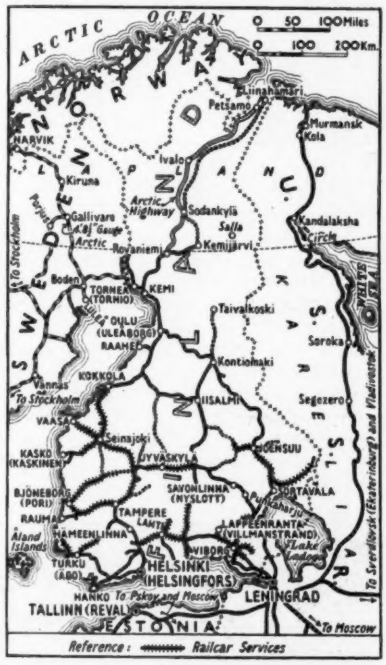
One of the small Finnish companies, the Jokioisten Railway, operates diesel and producer-gas cars on its 750-mm. gauge lines, and an 85 b.h.p. Daimler-engined car belonging to this company was illustrated on pp. 84-85 of the issue of this Supplement for July 12, 1935.

Estonia

A small number but great variety of railcars are used on the 900 miles of the Estonian State Railways. In addition to the two 115 b.h.p. eight-wheel 750-mm. gauge cars operating on the 94-mile Tallinn—Viljandi line, and the one 220 b.h.p. bogie car used on the Tallinn—Haapsalu and Tallinn—Paldiski routes, both described in the February 21, 1936, issue of this Supplement, there is a 265 b.h.p. diesel-electric car carrying 88 passengers and a small amount of luggage within an overall body length of 69 ft.; it is allowed a top speed of 90 km.p.h. (56 m.p.h.) and weighs about 50 tons when fully laden. There is also a bogie petrol car of 150 b.h.p. seating 86 third class passengers which works on the Fogeva—Tartu—Elva run, and four 115 b.h.p. petrol four-wheelers seating 66 passengers and running between Tartu, Petseri, and Valga.

Latvia

Several small diesel and producer-gas cars are at work on the 5-ft. State lines in Latvia, as well as a handful of petrol vehicles. The most recent are three long four-wheelers with an overall body length of 43 ft. and a wheelbase of 26 ft. 3 in. Apart from about 20 sq. ft. given up to two driving positions, and 28 sq. ft. to an entrance and exit vestibule, the whole of the floor space is utilised for passengers or luggage. This desirable result is achieved



Map of Finnish State Railways showing lines with railcar services; 18 out of the score of railcars are diesel-electric or diesel-mechanical

by using a 180 b.h.p. D.W.K. eight-cylinder horizontal engine mounted below the car floor together with its radiator and auxiliaries, and a Mylius four-speed gearbox and transmission driving one axle. The engine and gearbox are supported on a common subframe suspended from the car underframe at four points through rubber blocks. The car frame and body structure is of all-welded steel, and seats for 58 third-class passengers are provided on a tare weight of about 18 tons. A trailer can be hauled up to a top speed of 50 m.p.h.

Lithuania

Modern railcar operation on the lines of the Lithuanian State Railways dates from 1934-35, when six 130 b.h.p. Simmering diesel-electric four-wheelers were set to work on standard-gauge lines (see issue of this Supplement for July 13, 1934). These cars have a top speed of 46 m.p.h. and haul trailers of 15 tons weight up 1 in 200 grades at 37 m.p.h. The average distance covered in a year per car

Double-bogie diesel-mechanical railcar running on the 5-ft. gauge lines of the Finnish State Railways

is 96,800 km. (60,000 miles) with a fuel consumption of 42·5 litres per 100 km. and a lubricating oil consumption of 2·2 kg. per 100 km. Four much bigger double-bogie cars built by M.A.N. have been in service since the beginning of 1938. On each bogie is a 220 b.h.p. engine driving a Mylius five-speed mechanical transmission, which at the top engine speed of 1,100 r.p.m., gives track speeds of 15, 26, 39, 55, and 74 m.p.h. The radiators and fans are below the car floor. Steel body construction with copper-bearing steel panel plates is a feature, and there are 86 third-class seats. The 900-mm. (35½-in.) wheels are spread over a bogie wheelbase of 11 ft. 2 in. and the bogies themselves are pitched at 53 ft. 4 in. centres. Overall the car is 75 ft. long and tares 40 tons. On the quickest runs trailers up to a weight of 30 tons are hauled, and a greater weight on slower journeys; normally a special trailer taring 24 tons and carrying 83 passengers is used. Compressed-air brakes are applied to all wheels and on the level can stop the car in 750 yd. from 74 m.p.h. Five railcars are also at work on the 750-mm. gauge lines.

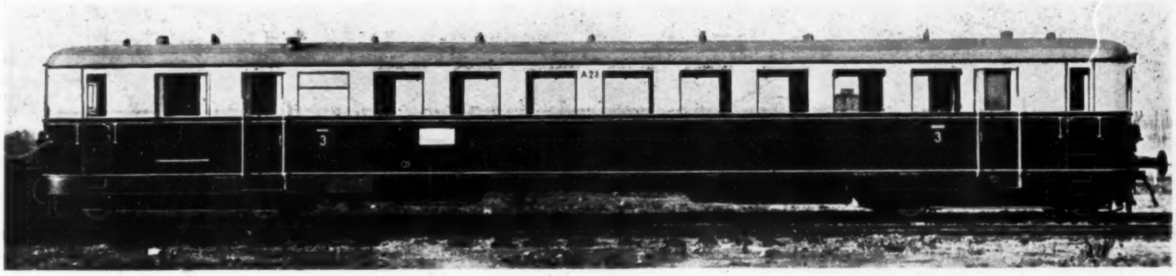
Sweden

Extensive electrification is the principal reason for the lack of medium-power and high-power railcars on the Swedish State Railways, but for some years light four-wheel and eight-wheel railbuses have been used with success, and about 80 of them are in traffic. In addition, there are four diesel and six petrol railcars of a somewhat heavier type running on the standard gauge.

State Rail Buses

Practically all of the railbuses are equipped with 130 b.h.p. Scania-Vabis petrol engines. All were built by Hilding Carlsson M.V., of Umea, and are of two types: a four-wheeler seating 24 and standing 26 passengers on a tare weight of 6¾ tons, and an eight-wheeler seating 46 and standing 34 on a tare weight of 10½ tons. Top speeds of 100 km.p.h. (62 m.p.h.) are possible, but usually are limited to 50-55 m.p.h. A small amount of baggage space is provided in each model and there is a lavatory in the large car. Provision is made in the bogie cars to fit a bigger engine, of 160 b.h.p., should this seem desirable in future. Many of the cars are used on small lines in the north and north-west and carry ski-racks on the side panels. The four-wheelers have a body length of 30 ft. 3 in. and a wheelbase of 14 ft. 9 in., and the eight-wheel cars a bogie wheelbase of 6 ft. 6 in., a bogie pitch of 26 ft. 11 in., and a body length of 41 ft. 6 in. Rubber shock-absorbing rings are inserted in the wheels between the centres and tyres. Heating of the car interior is by circulation of the engine cooling water. The high b.h.p. per ton, particularly in the four-wheeled cars having about 13 b.h.p. per ton of gross weight, permits fast start-to-stop schedules without the top speed exceeding 50 to 55 m.p.h.

Power bogie, with 240 b.h.p. engine and mechanical transmission, of the latest type of Finnish railcar



440 b.h.p. double-bogie standard-gauge diesel-mechanical railcar, Lithuanian State Railways

The yearly mileage taken over the whole stud of 55 four-wheelers is a little over 80,000 km. (50,000 miles), and the gross working cost amounts to about 24 öre per car-km., made up of:

Fuel..	3·5 öre
Lubrication	0·3 „
Crew wages	8·0 „
Maintenance, repair and overheads	6·3 „
Interest and depreciation	5·7 „

Swedish Private Lines

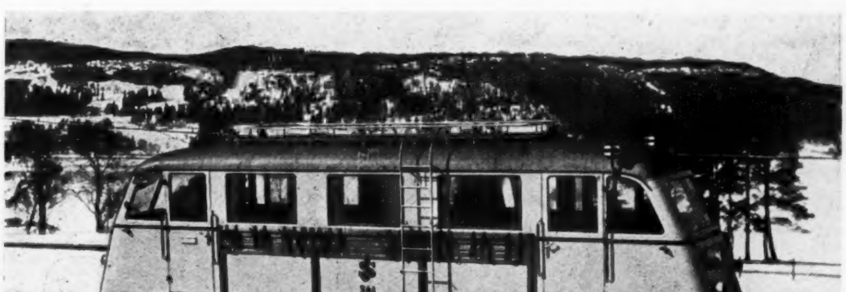
Successful diesel traction actually began in Sweden, in 1913, with a 75 b.h.p. Atlas diesel-electric car delivered to the Mellersta-Sodermanlands Railway, which is still running with a mileage of about a million to its credit, although the line over which it works is less than 20 miles long. In the 10 years which followed the introduction of the M-S car, several other private lines acquired similar cars of 75, 90, and 120 b.h.p., and by 1927 the power had risen to 300 b.h.p. The earliest cars were non-bogie eight-wheelers, but later the normal bogie arrangement was adopted. In all, there are about 125 railcars on the Swedish private lines.

Within the last five years or so the railcars delivered to the private lines in Sweden have been of much more up-to-date types. Some of the most powerful of them, for example the 480 b.h.p. double-bogie car built for the Malmö-Ystad Railway by the Kockums Mekaniska Verkstad, follow Danish practice. Asea electric transmission is general for these cars, among which is a 40-ton bogie car seating 64 passengers and capable of hauling trailers on the Uddevalla-Vänersborg-Herrljunga Railway. Originally this car was powered by two 200 b.h.p. Atlas high-speed bogie-mounted V engines of the type introduced about four years ago; this power unit did not prove a success, and the car has been rebuilt with two Saurer BXD engines equipped with Büchi pressure-chargers and set to give 225 b.h.p. at 1,500 r.p.m. The Asea electrical equipment has been retained and the engines and generators are bogie-mounted.

Fluid Transmission Applications

Standard designs of railcars have been evolved by Nydquist & Holm A.B., and are known as Nohab cars. Both diesel and petrol engines are used, and also the Hesselman type of kerosene engine; hydraulic transmission of the Lysholm-Smith pattern is applied to all the Nohab cars. Four-wheel 10-ton and eight-wheel 15- to 20-ton passenger railcars of 100-110 b.h.p. are built, and also double-bogie luggage railcars which are used as locomotives, and have installed engine outputs up to 640 b.h.p., and weights up to 40 tons. The designs are applicable to the 890-mm. (35-in.), 1,067-mm. (3 ft. 6 in.), and standard gauges found in Sweden.

As an example, the standard-gauge car taring 17½ tons and having a maximum speed of 80 to 110 km.p.h. (50 to 68 m.p.h.) according to the duty, has 28½-in. wheels spread over a bogie wheelbase of 6 ft. 6 in., and bogies pitched at 34 ft. centres. Also according to the requirements, either one or two bogie-mounted 105 b.h.p. Buda petrol or 110 b.h.p. Penta-Hesselman oil engines are used; with two engines the tare weight is about 19½ tons. Within a car body length of 43 ft. there are 53 third-class seats, and room for about 20 passengers standing. The car bodies are fabricated of welded steel, and braking is on a combined system of oil pressure and compressed air, actuating shoes on drums between the wheels. Control of the hydraulic torque converters and reversing gears is by compressed air. A heating stove is installed in the car to supplement the engine cooling water.



One of the numerous fourwheel 130 b.h.p. petrol-mechanical rail buses used by the Swedish State Railways. The vehicle illustrated is fitted with ski-racks on the side, for service round the winter tourist centres in the north

New Railways in Mexico Inaugurate Diesel Operation

Shortage of water and general economics lead to adoption of oil-engine traction

By T. F. PERKINSON, General Electric Co. (U.S.A.)

ALL-RAIL communication between Yucatan and the remainder of Mexico will be a reality upon completion of a new railroad which is under construction by the government of Mexico. The line extends for a distance of 460 miles between the gulf ports of Puerto Mexico and Campeche, and will connect the United Railways of Yucatan at Campeche with the National Railways system at Puerto Mexico. The route of the new line lies inland from the Gulf Coast over relatively level terrain and through sub-tropical country in which water for steam locomotive boilers is at a premium. The line is to be held close to the foothills of the Sierra Madre del Sur, and the maximum elevation encountered will be 500 ft. above sea level; the maximum gradient is 1 in 100.

U.S. Frontier Line

In the north-western part of Mexico a rail connection is being laid between Fuentes Brotantes—a station on that portion of the Southern Pacific System (Inter-California Railway) which runs south of the U.S.-Mexico boundary—and Santa Ana, a point on the lines of the Southern Pacific of Mexico. When completed this line will provide an all-Mexican rail connection between terminals and will provide rail transportation for the agricultural products from Lower California to Mexican markets without passage through the United States.

This line also is through low-lying country, but is mostly over sandy desert, and the water problem is even more acute than for the Yucatan connecting line. The maximum grade is 1 in 74, for a short distance.

Analysis of the economies involved in the operation of these lines with diesel locomotives led to the adoption of this power for road as well as switching service. The initial order for locomotives was placed by the government of Mexico with the General Electric S.A., of Mexico, and two machines are now in operation. They are intended ultimately for switching service, but are at present being used in work-train service, assisting in the completion of the two rail projects.

General Particulars

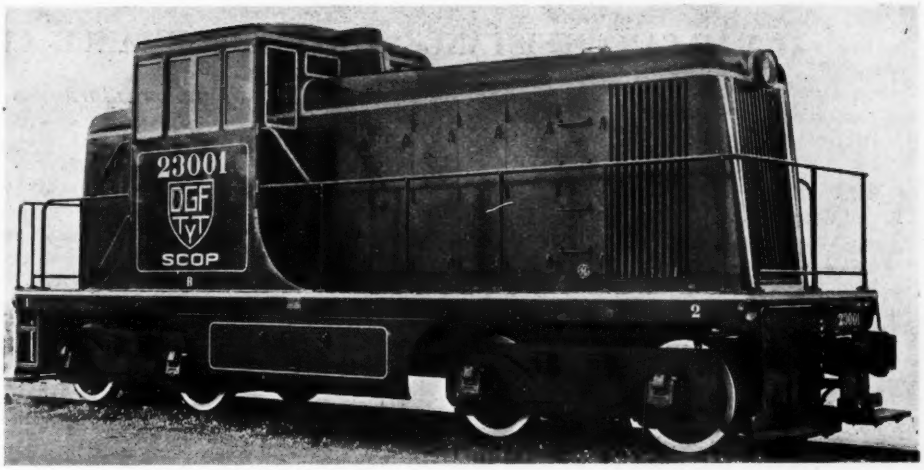
Of the double-bogie type with four traction motors, the locomotive has a single cab located about one-third of the way along the length. The 38-in. wheels are spread over a bogie wheelbase of 6 ft. 8 in., and the bogies themselves are pitched at 20 ft. 6 in. centres. Over coupler knuckles the length is 37 ft.; the maximum height is 13 ft. 10½ in. and the cab width 9 ft. 6 in. In full working order the weight is 58 Engl. tons, against which the maximum starting tractive effort of 39,000 lb. gives an adhesion factor of 3·33. The continuous rating tractive effort amounts to 17,900 lb. at 8·0 m.p.h.; at the top speed of 35 m.p.h. the tractive effort is about 1,500 lb. Full engine horsepower utilisation is afforded up to a speed of 17 m.p.h.

Mechanical Structure

Fabricated construction, with rolled-steel plates and shapes joined in casting-like structures by electric arc-welding, has been utilised throughout the locomotive superstructure and running gear. The compartment housing the engine and its cooling system is constructed so as to permit of its easy removal as a unit, thus facilitating the removal of the engine-generator set from the platform.

Trucks are of the conventional swivel-type, fully equalised with coiled steel springs. The trucks are completely fabricated with the exception of the journal boxes, which are of the standard ARA cast-steel type with 5½ in. by 10 in. journals. The straight-and-automatic air brake system is of the Westinghouse type and includes two

Map of the railways in Mexico showing the two new lines—one along the U.S. border by Lower California, and the other near Yucatan, which are to be operated by diesel locomotives



One of the General Electric (U.S.A.) diesel locomotives weighing 58 tons supplied to the Mexican Government for use on new standard-gauge lines in different parts of the country

brake cylinders, one for each truck, with single-shoe brakes working on the wheels. The ARA couplers utilise no draft-gear, but are carried in standard cast-steel pockets which are bolted to the end plates of the platform structure, the stresses being kept away from the bogie.

Lubricating oil-coolers and engine cooling water radiators are carried in three sides of the fan compartment, which is located in one end of the engine compartment. Greater than normal cooling surface has been furnished for both oil- and water-cooling services because of the high ambient temperatures under which the locomotives are to work. Decorative and protective grille-work has been furnished for each radiator assembly. This grille-work is duplicated in the end of the control compartment at the opposite end of the locomotive for the sake of symmetry in appearance.

Power Plant

A six-cylinder Cooper-Bessemer 500-b.h.p. 750-r.p.m. four-stroke engine direct-connected to a General Electric generator furnishes power for traction and for the operation of the auxiliaries. The cylinders have a bore of $10\frac{1}{2}$ in. and a stroke of $13\frac{1}{2}$ in. The 380-kW (continuous) generator is connected rigidly to the engine crankshaft without flexible couplings of any kind, and is mounted on an all-welded steel box sub-base which also carries the oil engine.

The generator characteristics are such that the engine can be loaded—but not overloaded—to rated capacity over a wide range of locomotive speed. The control of engine-generator loading is entirely automatic for any particular setting of the operator's control handle. The self-excited generator, in conjunction with the speed-torque characteristics of the engine, which rise with a reduction in engine speed, permits full utilisation of engine power over a wide range of locomotive speed without undue loss of power because of engine-generator speed regulation. Thus the output characteristic is obtained without the use of external generator load-regulating devices of any kind. A separate starting winding on the generator permits initial engine starting with power furnished from the storage battery.

Controls

The d.c. series-wound force-ventilated traction motors are connected permanently two-in-series with two such groups permanently in parallel. Full-field and one step of reduced field operation of the traction motors are provided, the latter connection being obtained automatically at the proper time under the control of field shunting relays which function with no attention on the part of the operator. The transfer from full to reduced traction-motor field strength is arranged to occur at a point such that best utilisation of the engine output results. Each motor has a continuous rating of 108 h.p., and drives the wheels through single gears with a ratio of 16 : 81, equal to a reduction of 1 : 5·06.

One operating station, arranged for single-unit control with electro-pneumatic and electro-magnetic control devices, is provided. A 56-cell lead-acid type of storage battery furnishes control energy at 112 volts, and is also used in conjunction with the starting winding on the generator for engine-starting purposes. The control devices such as contactors, regulators, resistors and relays are mounted on the cab wall at the auxiliary end.

Auxiliary Electrical Equipment

A double-voltage compressor with a displacement of 60 cu. ft. a min. supplies air for operating brake and control apparatus. The control for the compressor driving motor is arranged so that when the engine is running at idling speed the low-voltage (125 volts) motor is connected across the generator armature under the control of the governor-controlled compressor contactor. The excitation of the generator is controlled at idling by a voltage regulator which holds the generator voltage constant at 125 volts. When the engine is operating at speeds greater than the idling speed, the high-voltage (650 volts) motor is connected across the generator armature under control of a compressor motor contactor. With this method of compressor operation an adequate supply of air for braking purposes is assured at all times regardless of engine speed.

Battery and Auxiliary Drives

The 56-cell Exide-Ironclad battery is charged under regulated generator voltage while the engine is idling. A trickle-charge of the battery is also obtained while the engine is running at high speeds. All auxiliaries with the exception of the air compressor are driven directly by the engine through sheaves and belts from a crankshaft extension on the radiator end of the engine, and, in the case of one of the traction motor blowers, from an extension on the generator shaft. The radiator cooling fan—a 33-in. diameter four-blade propeller of the aphonic type—is connected through a system of V-belts, pulleys and gears to the crankshaft extension and runs whenever the engine is turning over. The fuel tanks, battery compartment, and other items of equipment are located below the platform between the trucks.

RAILCAR RESISTANCE AND PERFORMANCE CURVES

An investigation of the results of modern formulæ

By J. L. KOFFMANN

AMONG the problems involved in railcar design that of determining the power output required to propel a vehicle or train of a given weight over a certain route at a specified speed is of fundamental importance for the layout, and consequently in the first cost and maintenance expenses of the vehicle concerned.

Power is the rate at which work is done on a moving body, and is given by :

$$N = \frac{dW}{d_s} = T\frac{d_s}{d_t} = T \times V \qquad (1)$$

where N is the work in h.p., T the tractive effort in lb., S the distance in miles, and V the car velocity in m.p.h. In substituting the values concerned in formula (1) we obtain :

$$N_{h.p.} = \frac{T \times 5{,}280}{3{,}600 \times 550} = \frac{T \times V}{375} \qquad (2)$$

No allowance has been made for the power absorbed for various auxiliaries or for the losses in the transmission. When dealing with the first it must be borne in mind that the power required for radiator fans depends upon the climatic conditions, and that required for lighting is governed by whether a car is operating solo or whether trailers are being hauled. The power requirements for maintaining the power supply for brakes and auxiliaries will be higher with vacuum than with compressed brakes. On the average, the power absorbed by the auxiliaries varies between 5 and 10 per cent. of the total engine output, being lower with larger units due to a more favourable average constant load.

Losses in Gear Drive

The losses in mechanical transmission with modern spur gears are 98 to 99 per cent. with two gears in mesh and this value is reduced to 96·5 or 97 per cent. after making allowance for the shaft bearings, lubrication, and ventilation of the casing. Further, allowances must be made for losses in the intermediate gearing when driving two axles from a common gearbox, the axle drives, and the cardan shafts and universal joints. The average efficiency for a mechanical transmission between engine and wheels is 90 to 92 per cent. in direct gear, and for intermediate gears with two trains of wheels in mesh this value drops to 84 to 87 per cent., irrespective of the car speed. As an average, the overall efficiency of the power plant of a railcar with mechanical transmission can be assumed to be 82 per cent. as a maximum, and with this figure we obtain

$$T_{lb.} = \frac{0{\cdot}82 \times 365 \times N}{v} = \frac{300\, N_{(h.p.)}}{V_{(m.p.h.)}} \qquad (3)$$

The values obtained for the tractive effort in accordance with the above formula for different engine outputs are plotted in Fig. 1.

Car Resistance

The next item of importance in determining the possible car speed is the tractive resistance encountered. There are over one hundred formulæ dealing with the resistance

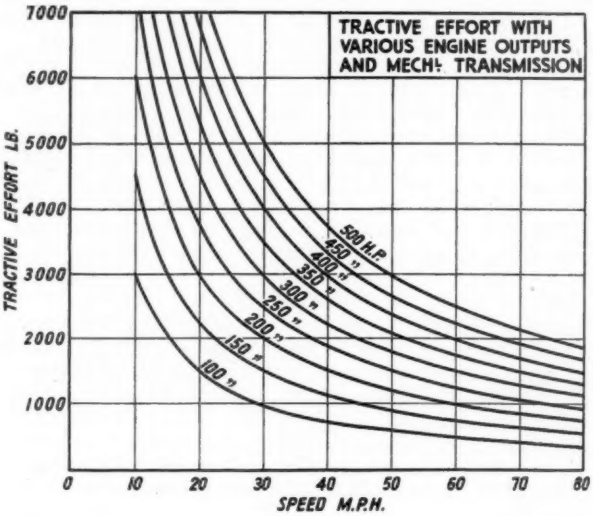


Fig. 1 (above)—Graph showing the theoretical tractive effort available at the rails with a variety of engine powers

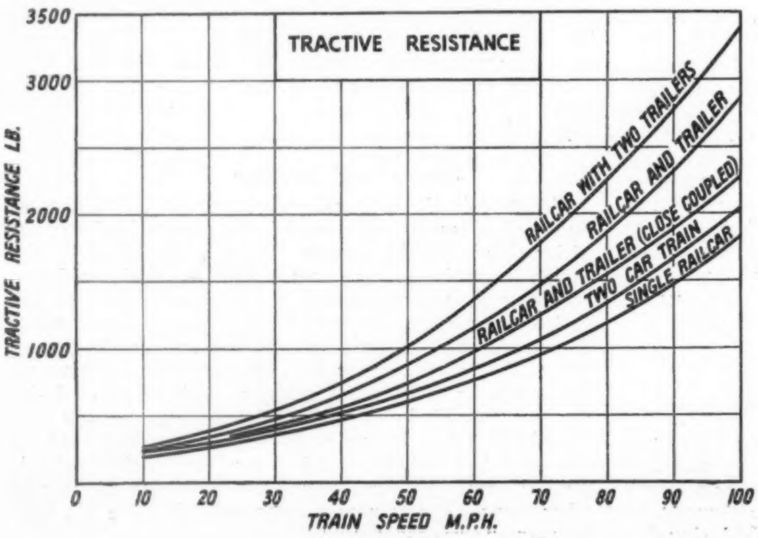


Fig. 2 (left)—Resistance values, obtained from Reichsbahn formulæ, for normal types of railcars and railcar-hauled trains

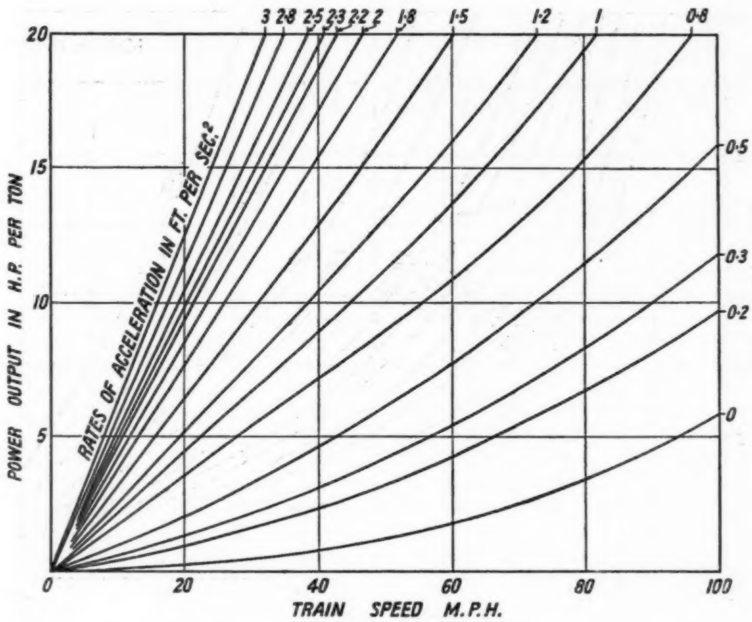


Fig. 4 (left)—Rates of acceleration obtainable in relation to available b.h.p. per ton of railcar or train weight. The curve marked O simply shows the minimum power output required to achieve a certain speed on the level after running a considerable distance

of locomotive-hauled trains, either steam or electric, developed by various railway companies and manufacturers for different types of rolling stock, gauge, and weather conditions, with results varying as much as 100 per cent., but the formulæ developed for multiple-unit electric trains and diesel railcars are very limited in number. Of these, the formula evolved by the German State Railways in 1933 has been widely used. As applied to a railcar hauling up to three trailers it is in the form :

$$R=5\cdot5W_1+0\cdot125c_1A_1\,(0\cdot16V)^2+n[3\cdot3W_2+0\cdot125c_2A_2\,(0\cdot16V)^2] \quad \ldots\ldots\ldots\ldots \quad (4)$$

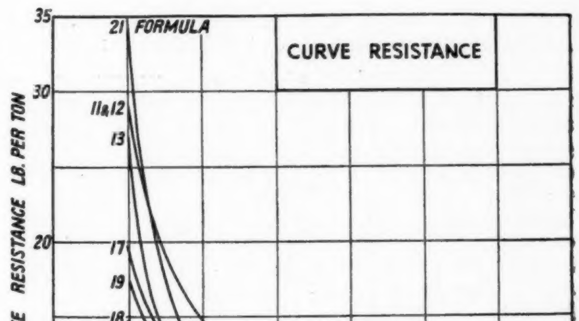
Herein R is the total tractive resistance in lb., W_1 the weight of the railcar in tons, W_2 the weight of each trailer in tons, A_1 and A_2 the frontal area in sq. ft. of the railcar and trailers respectively, and n the number of trailers. The factors c_1 and c_2 for the railcar two types respectively are 0·85 for double-bogie cars with square ends, and 0·5 for rounded ends ; for a four-wheeler the values are 0·75 and 0·45 respectively. The values for trailers are 0·25 to 0·3 for square-end units and 0·2 to 0·25 for round ends.

The first component in this formula represents the rolling resistance, which in a general way is not influenced by the car speed, and in the above formula has the value of 5·5 lb. per ton. The second part represents the air resistance, which varies almost as the square of the car speed. In common with other train resistance formulæ the values obtained are valid for still air only and should head winds be encountered allowance must be made for these to cover the increased relative air velocity.

In 1936 the above formula (4) was supplemented by more detailed expressions as follow :—

Single railcar :
$$R = 4\cdot4\ W_1 + 0\cdot062\ A_1\ (0\cdot16\ V)^2 \quad \ldots\ldots\ldots\ldots \quad (5)$$
Railcar and ordinary trailer :
$$R = 4\cdot4\ (W_1 + W_2) + 0\cdot1\ A_1\ (0\cdot16\ V)^2 \ldots\ldots\ldots\ldots \quad (6)$$
Railcar and close-coupled trailer :
$$R = 4\cdot4\ (W_1 + W_2) + 0\cdot08\ A_1\ (0\cdot16\ V)^2 \ldots\ldots\ldots \quad (7)$$
Twin-car train :
$$R = 5\cdot5\ W_T + 0\cdot062\ A_1\ (0\cdot16\ V)^2 \quad \ldots\ldots\ldots\ldots \quad (8)$$
Triple-car train :
$$R = 5\cdot5\ W_T + 0\cdot075\ A_1\ (0\cdot16\ V)^2 \quad \ldots\ldots\ldots\ldots \quad (9)$$

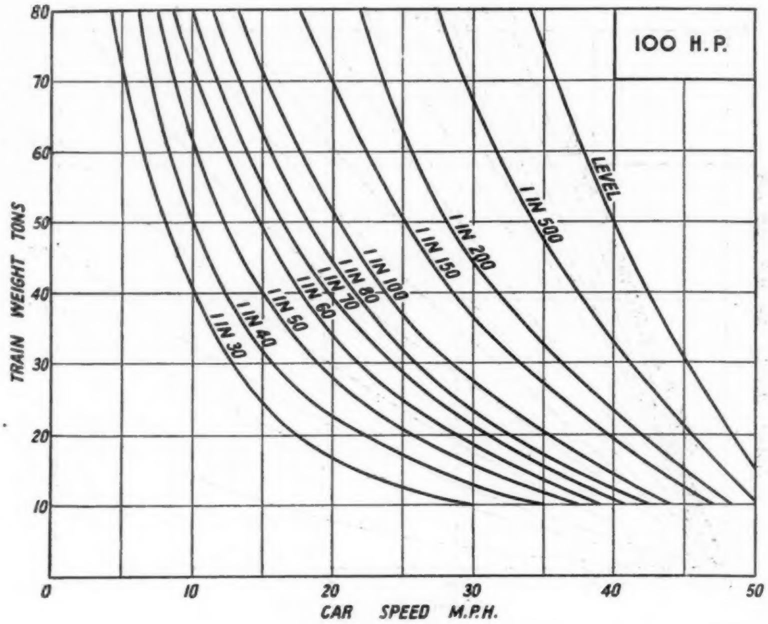
Fig. 3 (below)—Resistance on curves obtained from formula 11 to 14 and 17 to 21, covering standard-gauge and narrow-gauge lines



More recently the resistance values for streamlined twin-articulated diesel trains of the *Flying Hamburger* type, the triple-car articulated, and four-car non-articulated high-speed diesel sets have been made public. The formulæ for these resemble (8) except that the rolling resistance coefficient is only 3·3 and the air resistance factors are 0·056, 0·075, and 0·089 respectively.

For the purpose of comparison the resistance values as obtained in accordance with formulæ (5) to (8) for a single 50-ton car, a 25-ton car with a 25-ton trailer, and a 25-ton car with two 12·5-ton trailers are shown in Fig. 2. As the multiple-unit operation of railcars, is becoming more and more popular and ultimately may to a large degree replace railcar and trailer trains, the performance graphs accompanying this article were prepared for two-car units, the values obtained being based on formulæ (3) and (8). The curves show the speeds possible from a given engine output, with trains of various weights and on different gradients, but it must be borne in mind that the actual

Fig. 5 (right)—Example of train weights in relation to track speed and gradients which can be operated with an installed engine capacity of 100 b.h.p., and using the resistance formulæ contained in this article



speed on grades depends on the gear ratios available. The additional tractive resistance due to gradients is:

$$Rg = 2{\cdot}2\ (W_1 + n\ W_2)\ S \quad \text{.........} \quad (10)$$

where S is the value of the incline per thousand. The fact that S represents the value for the tangent of the gradient angle instead of the sine is permissible, as the values for both are almost equal for values up to 1 in 10 (tan. 6 deg. $= 0{\cdot}1051$; sin. 6 deg. $= 0{\cdot}1045$).

With the performance curves shown no allowance has been made for tractive resistance due to curves; the values for the latter can be found from any convenient formulæ. Among these are:

Röckl:

$$R_c = \frac{4{,}700}{r - 180} \text{ lb./ton} \quad \text{...............} \quad (11)$$

and

$$R_c = \frac{3{,}400}{r - 100} \text{ lb./ton} \quad \text{...............} \quad (12)$$

for curves with a radius r more than 1,000 ft. and less than 1,000 ft. respectively; for metre-gauge track:

$$R_c = \frac{2{,}900}{r - 92} \text{ lb./ton} \quad \text{...............} \quad (13)$$

Blondel and Dubois:

$$R_c = 880\,\frac{g}{r} \text{ lb./ton} \quad \text{...............} \quad (14)$$

where g is the track gauge in ft.

Wood (for bogie railcars):

$$R_c = 0{\cdot}45 + \frac{1{,}320 + 220\,b}{r} \text{ lb./ton} \quad \text{......} (15)$$

where b is the bogie wheelbase in ft.

The University of Illinois published a formula showing the tractive resistance as a function of car speed:

$$R_c = \frac{370}{r}\,V \text{ lb./ton} \quad \text{...............} \quad (16)$$

Protopapadakis (standard-gauge):

$$R_c = \frac{1{,}685 + 228\,b}{r} \text{ lb./ton} \quad \text{.........} \quad (17)$$

$$R_c = \frac{1{,}260 + 170\,b}{r} \text{ lb./ton} \quad \text{............} \quad (18)$$

for summer and winter conditions respectively, the difference being due to variations of the values of the coefficient of friction.

For metre-gauge the Protopapadakis formulæ are:

$$R_c = \frac{1{,}150 + 230\,b}{r} \text{ lb./ton} \quad \text{............} \quad (19)$$

$$R_c = \frac{865 + 174\,b}{r} \text{ lb./ton} \quad \text{............} \quad (20)$$

Italian State Railways:

$$R_c = \frac{5{,}800}{r} \text{ lb./ton} \quad \text{............} \quad (21)$$

The values obtained in accordance with formulæ (11–14 and 17–21) are shown in Fig. 3.

When designing a car for a certain specified duty, the question of the rates of acceleration required is important, especially with vehicles intended for suburban or short-distance interurban operation where there are frequent stops and speed checks.

Considering the mass M it must be remembered that in addition to the linear acceleration of the car there is a rotary acceleration of the wheels and attached masses. Therefore, the mass of the car is assumed to be increased by an amount which with diesel-mechanical railcars varies between 5 and 10 per cent., and which may be taken here as 7 per cent. With the corrected mass $M_1 = 1{\cdot}07\,M$, the equation of motion is:

$$F = \frac{2{,}204}{32{\cdot}2} \times 1{\cdot}07 \times W \times a = 73{\cdot}5W \times a \ \text{...} \quad (22)$$

where F is in lb., W in tons, and a is the rate of acceleration in ft. per sec. per sec. The specific acceleration resistance in lb. per ton is:

$$r_a = 73{\cdot}5a \quad \text{.....................} \quad (23)$$

$$a = \frac{F}{73{\cdot}5W} - \frac{\pm r_g}{73{\cdot}5} \text{ ft. per sec. per sec.......} \quad (24)$$

Referring back to equation (2) we obtain:

$$a = \frac{5N^1}{V} - \frac{r \pm r_g}{73{\cdot}5} \text{ ft. per sec. per sec. ......} \quad (25)$$

where N^1 is the engine output in h.p. at the wheel rim and V the speed in m.p.h., the values for r and r_g are in lb. per ton, and can be calculated from equations (4) to (10).

Diesel Railway Traction

RETROSPECT AND PROSPECT

IT would be untrue to say that, when we wrote the editorial for our annual review number in 1939, we had little idea that within the year Europe would once again be plunged into the miseries of war. We had every expectation that it would, and we devoted the whole of the front page of the January 20, 1939, issue of this Supplement to an indication of the causes which then were leading from intensified economic war to military war. Since the beginning of September there has been no spokesman of the Government nor any industrial leader who has given the slightest hope that the causes underlying this war will be rectified so that the earth's abundance—actual and potential—may be distributed without restriction to the earth's population, and thus banish economic war and the main risk of military war. Indeed, in the time which they have been able to spare from prosecuting the war efficiently, statesmen and many spokesmen of industry have been pressing for a continuation of just those conditions and methods which brought about the present war, notably an intensive drive to maintain exports, not for the reason that we have a surplus of certain commodities to export in exchange for the equivalent of those in which we are deficient, but because our industry does not distribute, in the form of wages, salaries, and dividends, enough money for the people in this country to buy all the goods they make and need. Therefore money, not goods, must be obtained in exchange for exports.

Export Loans

Few of our readers will have failed to note the growing habit of granting loans overseas so that those living abroad may buy our goods, although there is little hope of the repayment of the loans. It would seem to be a much more satisfactory procedure to grant our own people such loans, or subsidies, first, to allow them to buy any of the goods and services produced in this country. Indeed, until the inauguration of a system which will permit the well-nigh unlimited production of all kinds of beneficial goods and services to be made freely available, neither the diesel traction nor any other beneficial industry need expect anything but minor booms alternating with major slumps, wars, and setbacks due to international or exchange situations.

As Colonel W. A. Bristow, Vice-President of the Institute of Fuel, said recently, the financial system by which industry is operated is a powerful deterrent to progress. Its deterring and frustrating effect goes much further than purely manufacturing industries: it strikes at the very root of railway operation itself. The operating ideal at which to aim is to provide every vehicle or permanent set of vehicles with its own self-contained motive power. As far as passenger traffic is concerned there is not the slightest technical or engineering reason why this should not be so. The only preventive is financial, by which the progress of science and invention is hindered instead of being made freely available to the railways, to the manufacturing industries, and to the public—in fact, to everyone except those in whose hands is the present-day power of financial credit creation. Yet one of the disquieting features of diesel traction during the past two years or so has been the gradual increase in the tractive power of the average railcar, almost entirely because of the desire to haul trailers and more and more trailers, and thus to replace a steam train without any change in timetables, rolling-stock rosters, or other long-accepted routine practices of the traffic department. Applications of such railcars have been called good railroading; fundamentally they are extremely unsound railroading.

The Function of Railcars

As far as passenger traffic is concerned, the only way for a railway to obtain greater gross and net revenues is to give the public more of what the public wants, and what the public does not want is a train of anything from six to 18 carriages hauled by a fancy locomotive or railcar running twice a day and once a night. The public wants a great increase in frequency, a higher standard of comfort, punctuality far above the present shocking level, faster overall speeds in general instead of in particular, and a reduction in fares. Under every one of these headings the railcar can give more fruitful results than steam traction in the hands of locomotives. Putting a string of trailers behind a railcar is simply bringing the formation down to the level of a steam train, and nullifying more than half of the potential advantages of railcar operation. Diesel traction habitually is more economical than steam traction on the basis of cost per mile, and it is worth noting that the one large-scale example in which main-line diesel traction is also considerably more economical than steam traction *per seat-mile* is in Holland, where railcar-trains are worked in the proper manner, that is, by coupling the basic unit in multiple up to totals of nine or a dozen vehicles, and driving by one man. Despite such an example, the practice of hauling long trains of trailers is growing, on the assumption that facilities must be cut down to equal the ever-dwindling amount of money in the pockets of the public. Until the amount of money available is increased to equal the prices of goods and services available, manufacturers of diesel and other equipment must be content to carry on cut-throat competition, have further rationalisation forced on them, see practically every form of private enterprise eliminated, and be subject to wars and slumps.

THE RAILWAY GAZETTE

Read wherever there are Railways

DIESEL TRACTION PROGRESS IN 1939

Locomotives and railcars valued at over £12,000,000, and in powers from 50 to 4,000 b.h.p., were ordered or acquired by more than 120 railways

TWO activities of the year in England stood out above all others: first, the introduction of 20 heavy six-wheel diesel-electric shunters in the mineral marshalling yard at Toton, L.M.S.R., and secondly the progress made in the construction of the score of A.E.C. railcars of the diesel-mechanical twin-engine pattern ordered in 1938 by the Great Western Railway.

Great Western Railway

The decision to push ahead with the G.W.R. cars as rapidly as the raw material situation in the second half of the year allowed, is particularly noteworthy at a time when the imports of fuel oil for ordinary commercial purposes are restricted. The position is that on certain branch and secondary lines the economical working problem has become intensified as a result of the war, and the lower operating costs of diesel traction will enable the cars to offset the lower revenue now being earned. Several interesting technical improvements have been made in the new cars compared with the 18 existing cars. A new direct injection A.E.C. engine is installed on each side of the car and is set to give 105 b.h.p. at 1,650 r.p.m., water and oil cooling arrangements have been modified, and the controls of both engine and transmission have been simplified. All the cars except four arranged as two twin-car sets for the Birmingham—Cardiff service are intended for trailer haulage. Most of them are geared for a top speed of only 40 m.p.h., but two of them with dual-geared boxes have a top speed of 60 m.p.h. The unusual end contour of the earlier A.E.C. cars has been modified to something more approaching normal forms, giving a larger amount of useful space. The bodies are being built at Swindon.

L.M.S.R. Locomotives

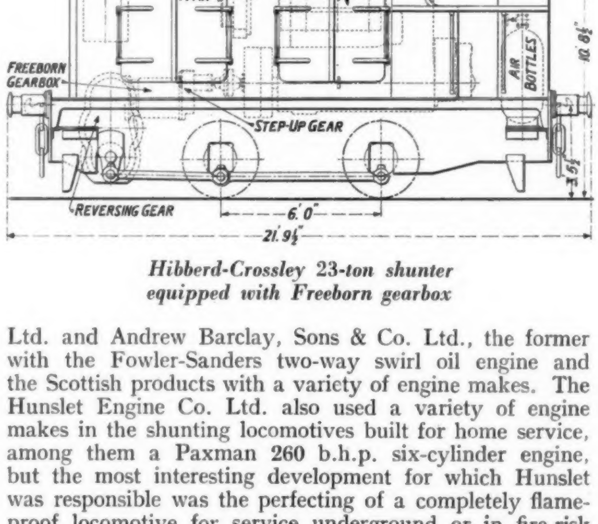
Features of the earlier Armstrong-Whitworth and English Electric 50-ton locomotives are incorporated in the score of locomotives set to work on the L.M.S.R. in the early summer. The mechanical portions were built at the company's works at Derby, and the electrical equipment by the English Electric Co. Ltd. The single-motor geared-jackshaft system evolved by Armstrong-Whitworth is perpetuated, and power is provided by the standard English Electric 350 b.h.p. six-cylinder engine driving an E.-E. generator. The weight of the 1939 locomotives is 55 tons with the 661-gal. fuel tanks full, and the starting tractive effort is 35,000 lb. Work has begun on another score of these locomotives; as before, power and transmission equipments are being supplied by English Electric, but work on the mechanical portions has not yet started either at the L.M.S.R. works or elsewhere. Several of the earlier L.M.S.R. diesel locomotives are now on war service, and since the beginning of the war the triple-car train with Leyland engines and hydraulic transmission has been withdrawn from regular service.

In Ireland the Northern Counties Committee of the L.M.S.R. put into traffic on the Belfast suburban services and other runs their third 260 b.h.p. twin-engined diesel-hydraulic railcar with Leyland engines and Lysholm-Smith transmission. No new diesel vehicles were acquired during the year by the Great Northern Railway of Ireland, but the cars at work passed the million-mile mark early in the year. The only other railway diesel project in the British Isles was work carried out by the L.P.T.B. in transforming an old machine into a diesel-electric locomotive with metadyne control, but the L.N.E.R. was to sanction an order for diesel cars, an intention postponed as a result of the war.

Shunting Locomotives

Diesel locomotives, practically all with mechanical transmission, were built in great variety for industrial shunting service in this country. A Crossley two-stroke engine of 82 b.h.p. was installed in a shunting locomotive for the Sandiacre works of Crossley Premier Limited, and operates in conjunction with a Freeborn gearbox which, as a result of the automatic gear change, has reduced the control to a throttle handle and a reverse; this locomotive worked for some little time in the L.M.S.R. sleeper depot. A 30-ton Hudswell-Clarke locomotive for Shell-Mex service in South America incorporates a Traction gearbox and fluid coupling, and is powered by a Gardner 8L3 engine of 200 b.h.p.

New construction of some magnitude was centred on standard locomotives built by John Fowler (Leeds) & Co.



Hibberd-Crossley 23-ton shunter equipped with Freeborn gearbox

Ltd. and Andrew Barclay, Sons & Co. Ltd., the former with the Fowler-Sanders two-way swirl oil engine and the Scottish products with a variety of engine makes. The Hunslet Engine Co. Ltd. also used a variety of engine makes in the shunting locomotives built for home service, among them a Paxman 260 b.h.p. six-cylinder engine, but the most interesting development for which Hunslet was responsible was the perfecting of a completely flameproof locomotive for service underground or in fire-risk areas; the equipment incorporates the latest pattern of Hunslet exhaust-gas conditioner and a Gardner engine and ancillary fittings which comply with the Ministry of Mines requirements for flameproof electrical apparatus. Robt. Stephenson & Hawthorn's completed several diesel shunting locomotives with Crossley engines, Vulcan-Sinclair fluid couplings, and two-speed rotary gearboxes with an air-operated brake for the first speed and a Cooper multi-plate friction clutch for the second speed. The track speeds with top engine revs are 4 and 8 m.p.h.

Among what may be termed the Fowler non-standard locomotives is one of 220 b.h.p. and weighing about

34 tons. The above output is given by a Fowler-Sanders engine with six 7 in. by 9 in. cylinders, which is started by a 20 b.h.p. twin-cylinder petrol engine. The torque is transmitted to the 39-in. wheels through a Vulcan-Sinclair fluid coupling, a synchro-mesh three-speed gearbox built by Bostock & Bramley Limited to the designs of the Hydraulic Coupling & Engineering Co. Ltd., and a geared jackshaft and rods. At top engine revs the track speeds are 4, 7½, and 12 m.p.h., with corresponding maximum tractive efforts of 16,500, 8,800, and 5,500 lb.

Personnel

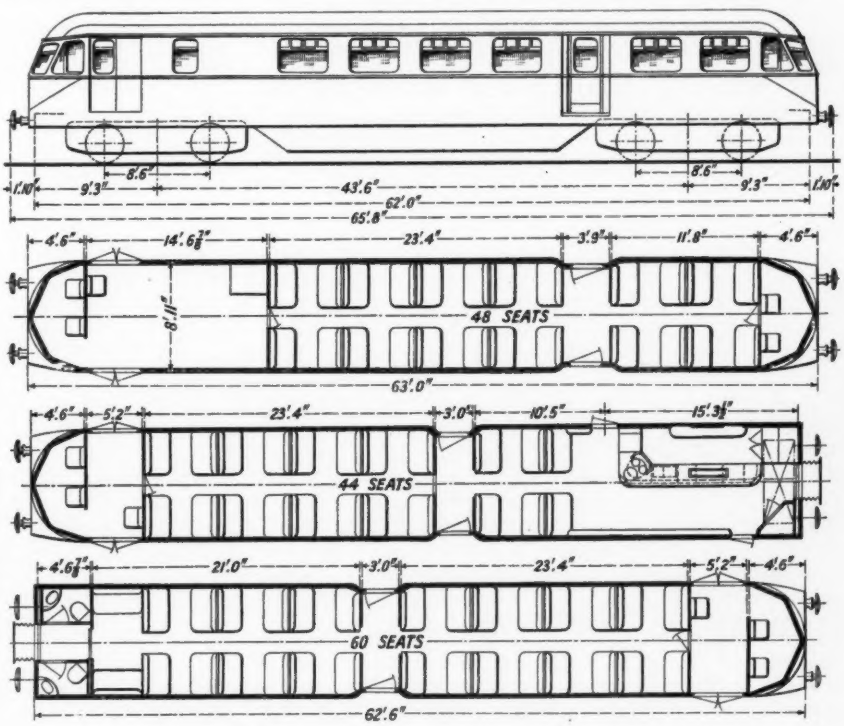
A reviewer of English diesel railway traction during 1939 who failed to mention H. F. Haworth and T. Hornbuckle would be guilty of serious omission. Haworth's personality was felt beyond the fields of hydraulic transmission and Leyland vehicles with which he was primarily associated, and his death removed a sound engineer and constructive critic. Even wider was the influence of "Tommy" Hornbuckle on diesel traction. Before his retirement in August, he had, as Chief Technical Assistant to the C.M.E. of the London Midland & Scottish Railway, fathered the development of diesel traction on the biggest British railway. His amazing knowledge of railway operation in its widest sense was always available to railwaymen and to manufacturers, and not a few diesel vehicles exported from England incorporate features originating in conversations with him.

France

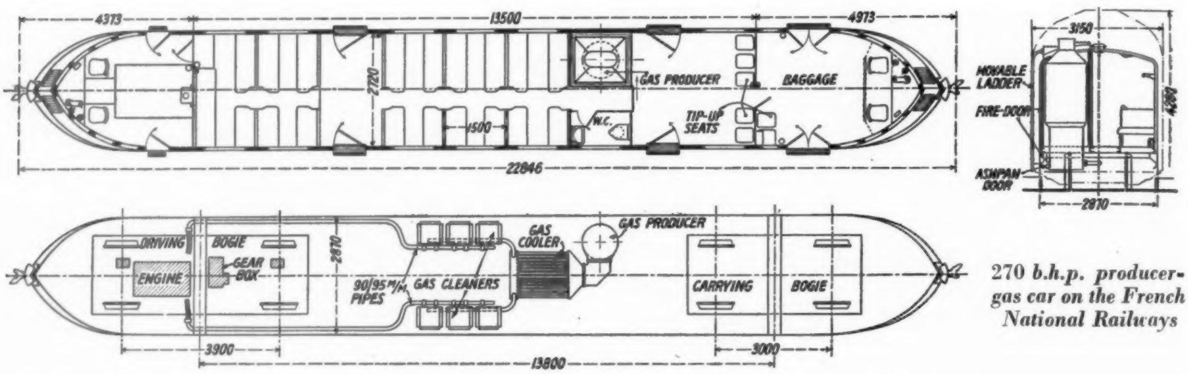
Over a period of two or three years the average power of railcars built for the French National Railways and its six constituents has risen gradually, and the cars set to work in 1939 were mainly of 500-600 b.h.p., generally with two engines, but in some examples with a single 500 b.h.p. C.L.M.-Junkers two-stroke opposed-piston engine. What now amounts to a modern standard car is a double-bogie vehicle with a Renault 300 b.h.p. or C.L.M. 250 b.h.p. engine at each end and a four-speed gearbox proportioned to give a top speed of 95 m.p.h. These cars are 85 ft. long and tare 40 tons; they have 64 seats, standing room for about 40 passengers, and luggage accommodation. Trailers are hauled in normal service. Further Decauville double-engined cars with Saurer 300 b.h.p. 12-cylinder V engines and electric transmission are being built for mountain lines on the ex-P.L.M. section. A development of the potentialities of diesel traction took place with the introduction on the Région du Sud-Ouest of a couple of two-power cars designed to operate from 1,500-volt d.c. on electrified sections and to derive power from two 250 b.h.p. Alsthom-Ganz oil engines on non-electrified lines. Designs have been prepared for a double-deck diesel car for suburban traffic using the same type of engine, but no vehicle has yet been constructed.

Locomotive construction in France has not attained any great magnitude, and the only activity in 1939 for home service was the completion of the ex-P.L.M. section's order for five diesel-electric shunting and transfer locomotives with pressure-charged Sulzer engines of 635 b.h.p. Compared with the earlier locomotives the arrangement has been changed to a single-cab design giving far greater facility in shunting than the old layout with a cab at each end. Proposals have been made to extend main-line diesel locomotive construction with a 3,000 b.h.p. single-engine unit, but the war has delayed further activity in this direction. Actually, sanction was given before the war for a general improvement programme to be spread over five years, and which included an allowance of 50 million fr. for main-line diesel locomotives, and 157 million fr. for railcars and diesel shunting locomotives and loco-tractors.

In common with most European systems the French National Railways have reduced both the number and the speed of fast runs, and as a large proportion of these were operated by railcars and railcar trains, the high-speed mileage by that form of traction has almost disappeared, but the cars are being used in slower-speed services. Renewed attention is being given to the possibilities of producer gas, although the National Railways did not



Diagrams of the 20 new double-engined 210 b.h.p. A.E.C. diesel-mechanical railcars now being delivered to the Great Western Railway. The top floor plan shows the normal seating arrangement, and the two bottom diagrams represent the layout in the twin-car sets for the Birmingham-Cardiff service. In addition, there is to be one car devoted solely to parcels and mail traffic



270 *b.h.p. producer-gas car on the French National Railways*

have particularly successful results with such cars in the two years before the war. One of the small Departmental railways south of Bordeaux has put into service five small charcoal-burning producer-gas railcars.

Belgium

Greatest proportionate advance during the year was made by the Belgian National Railways, which, beginning the year with 29 single cars, one twin-car train, and eight triple-car trains, put into traffic six new triples, 12 new twins, six big single cars, and was taking delivery of 50 small four-wheel cars of 150 b.h.p., which were ordered after observing the behaviour of six four-wheel and six bogie cars set to work early in 1939.

Two distinctive features are incorporated in the triple sets. First, the use of two Büchi-pressure-charged engines of the Maybach type, set to give 600 b.h.p. each; secondly, the incorporation of Voith hydraulic transmission with the special form of double-axle drive to the end bogies of the train. Considerable differences in the design of the mechanical portion were made compared with the eight triples introduced in 1936, and the maximum axle load was reduced from 20 to 18 tons by eliminating articulation of the coaches. The twin-car sets and the big single cars both have the same motive power unit, *viz.*, an eight-cylinder Carels-Ganz engine, a Vulcan-Sinclair fluid coupling, and a five-speed S.L.M.-Winterthur gearbox; the twin sets have one of these plants at each end of the train. The single cars are suited to trailer haulage, but a feature of Belgian National practice is that none of the multi-car trains is fitted for multiple-unit operation.

The 50 small cars built by Brossel have 150 b.h.p. engines and mechanical transmission with a gearbox based upon heavy lorry practice. They are intended solely for light branch and secondary lines and haul light trailers. Since the war began, the design of some of the cars then to be finished was changed to incorporate a producer-gas plant.

Holland

The gradual elimination of steam traction, even for international trains, is being accomplished by the Netherlands Railways in two ways, first by the extension of electrification, and secondly by increase in diesel train services. Since 1934 it has been the policy to operate fast and heavy trains with triple-car diesel sets coupled in multiple-unit to give totals of six, nine or 12 cars a train, and a desired extension of this practice led to a decision to use a five-car set as a basis when new stock was ordered in 1939. Consequently 18 five-car trains, each powered by three Maybach engines pressure-charged on the Büchi system to give 650 b.h.p. each at 1,400 r.p.m., were ordered. Werkspoor is responsible for the mechanical portions of the power cars and for the partial manufacture and the assembly of the engines. Electric transmission is to be embodied, and the three sets of engines, generators and auxiliary apparatus are to be carried in line in the second car of the set, which is to be used entirely for power equipment, luggage and parcels. These trains will seat second and third class passengers. Two spare power sets comprising a new type of Stork-Ganz engine and electrical transmission have been ordered for these trains.

The operation of long diesel trains made up by coupling in multiple-unit sets of fixed formation, has been a great success in Holland during the last four years, and the operating costs per mile and per seat-mile are both well below the values for equivalent steam trains.

Germany

The principal activity during the first eight months of 1939 was the prosecution of the big construction programme inaugurated towards the end of 1938, and comprising principally the building of about a score of luggage cars with Maybach engines equipped with Büchi pressure-chargers to give a maximum of 650 b.h.p.; over 30 double-bogie passenger cars with 410 b.h.p. Maybach engines, and something like the same number with 650 b.h.p. Maybach pressure-charged engines; in addition 25 to 30 cars of 220 to 250 b.h.p. were under construction, many of them with pressure-charged engines.

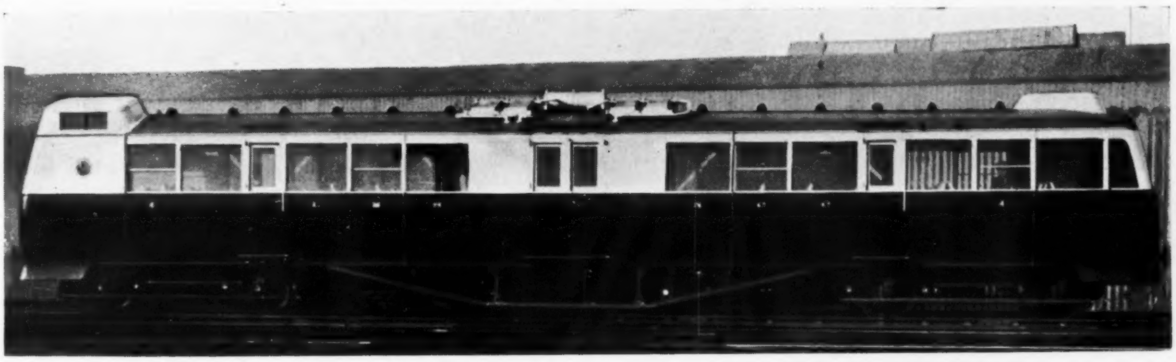
As in France, the power output of the normal Reichsbahn heavy railcar has increased over several years from 210 b.h.p. to 300-330 b.h.p., 410-420 b.h.p., and now to 600-650 b.h.p. as the desire increased to change from the true function of the railcar and simply use a powerful car as a substitute for a steam locomotive with the least possible extraneous changes.

The year 1939 also saw the completion of delivery of the 14 triple-car 1,200 b.h.p. diesel-electric *schnelltriebwagen* ordered in 1937, and the introduction to experimental service of a special diesel-hydraulic triple-car train, the *Flying Silver Fish,* powered by two 600 b.h.p. pressure-charged Maybach engines and incorporating ideas of Kruckenburg. This train attained a speed of 133·6 m.p.h. (215 km.p.h.) in June—a world record for diesel traction. With the beginning of the summer timetables, the *schnelltriebwagen* services were increased and accelerated, but the fastest schedule remained at just over 82 m.p.h.

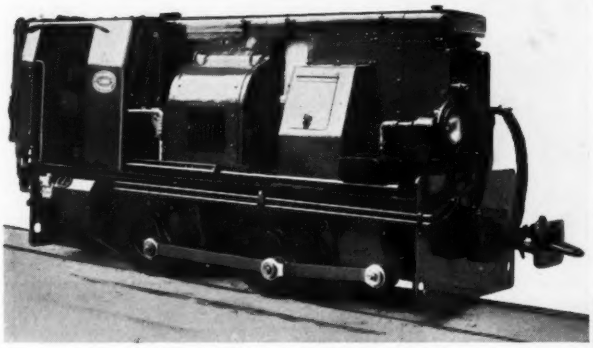
Denmark

New diesel construction has slowed down in Denmark over the last year or two, but nine of the standard MO-type double-bogie cars powered by two 250 b.h.p. engines at one end, were ordered by the State Railways, and will be delivered during 1940. At the moment there are 50 cars of this general type in traffic. A projected development is a twin-car close-coupled set with two pressure-charged 500 b.h.p. engines in one car and the electric traction motors on the bogies of the other car; this set is intended

Diesel Locomotives and Railcars of 1939

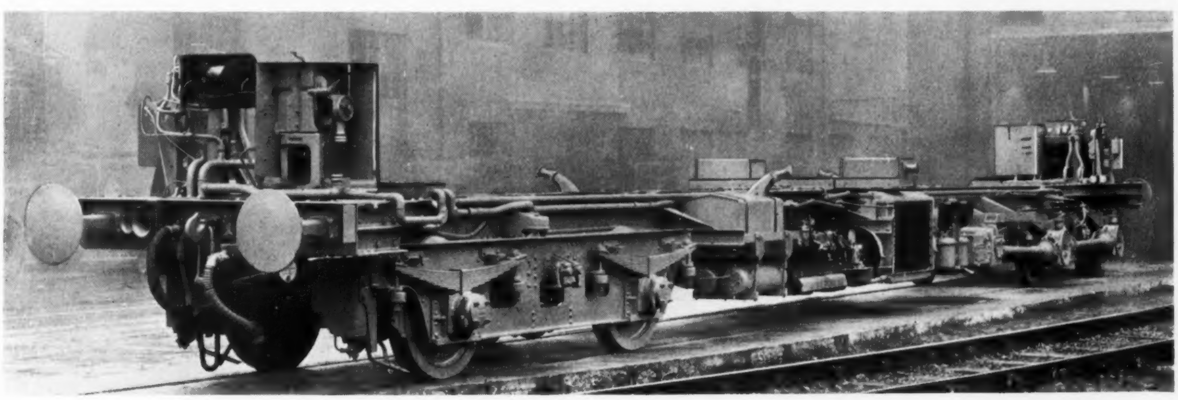


The third 5 ft. 3 in.-gauge 260 b.h.p. diesel-hydraulic railcar operating on the northern Belfast suburban services of the L.M.S.R. (Northern Counties Committee)

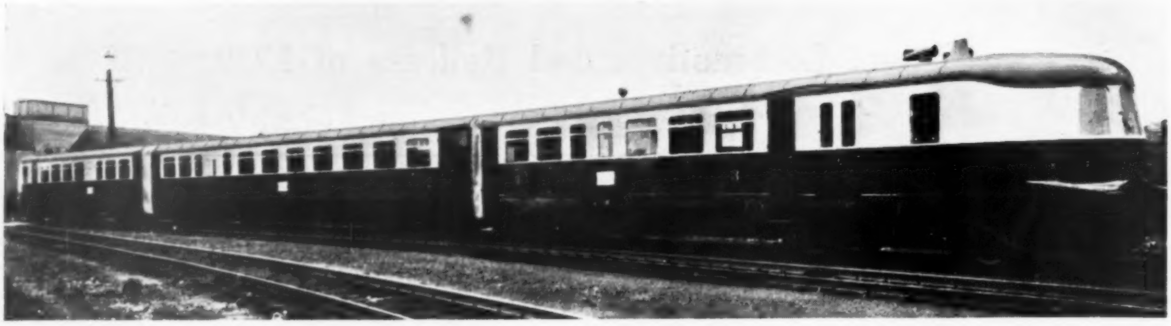


Hunslet completely flameproof diesel-mechanical locomotive for 2-ft. gauge. The engine is a 25 b.h.p. Gardner model and the Hunslet four-speed transmission gives a top speed of 12 to 15 m.p.h.

350 b.h.p. 55-ton diesel-electric locomotive. A score of these locomotives with English Electric power and transmission equipment were set to work in 1939



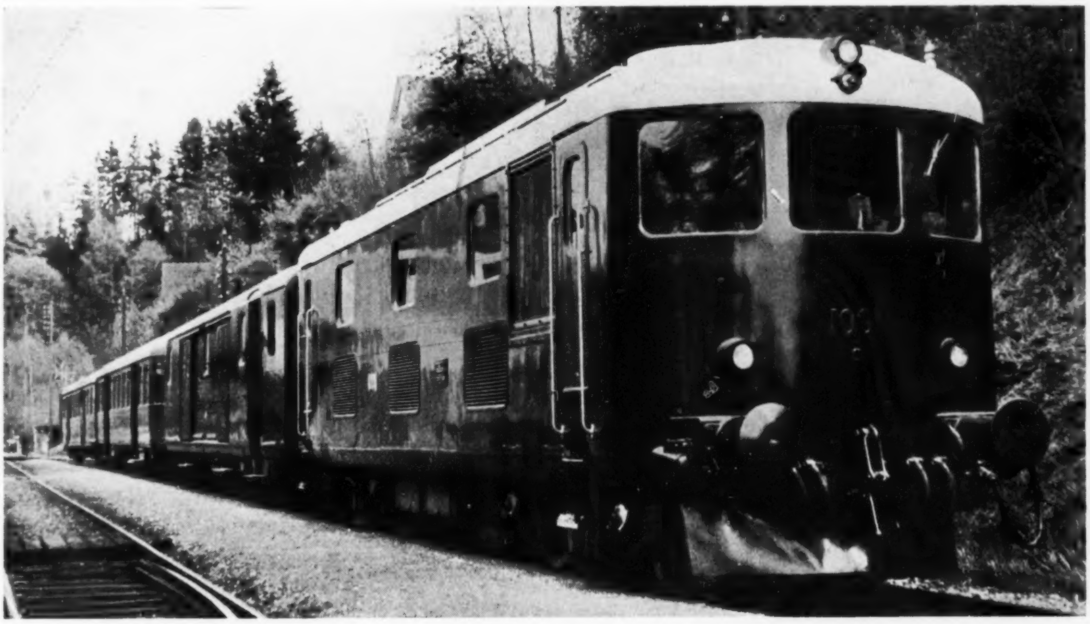
Chassis of one of the new twin-engined A.E.C. diesel cars for the Great Western Railway as it ran trials on the Southall-Brentford branch towards the end of 1939



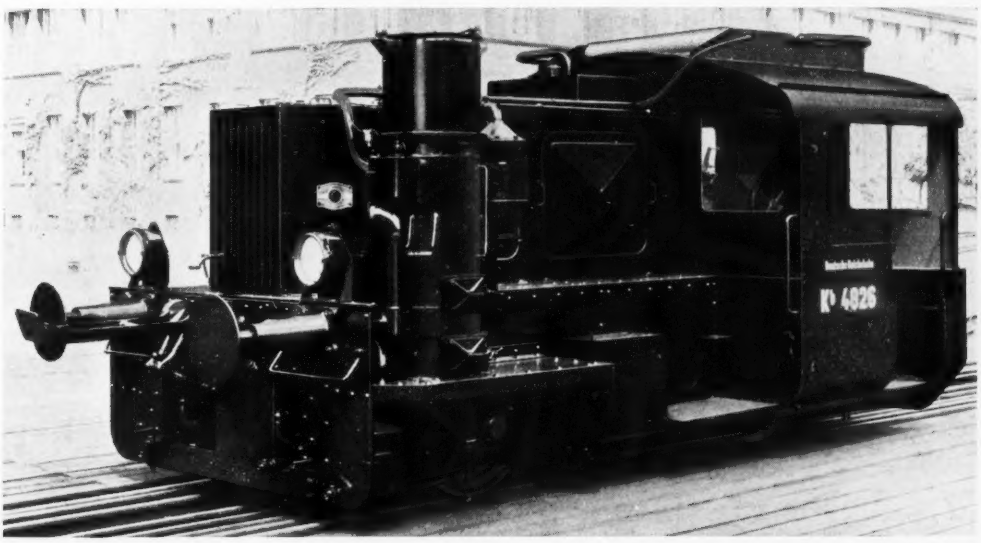
One of the six new 1,200 b.h.p. three-car diesel-hydraulic trains of the Belgian National Railways. The tare weight is 134 tons and the triple-converter transmission is suited to give a maximum track speed of 100 m.p.h. Non-articulated construction is used compared with the articulated form of the trains built in 1936

One of the three double-bogie producer-gas railcars of the French National Railways, built by De Dietrich. The car has a producer of the Panhard up-draught type using charcoal as fuel; the engine is a Panhard-Levassor 12-cylinder V model giving 270 b.h.p. at 1,750 r.p.m.

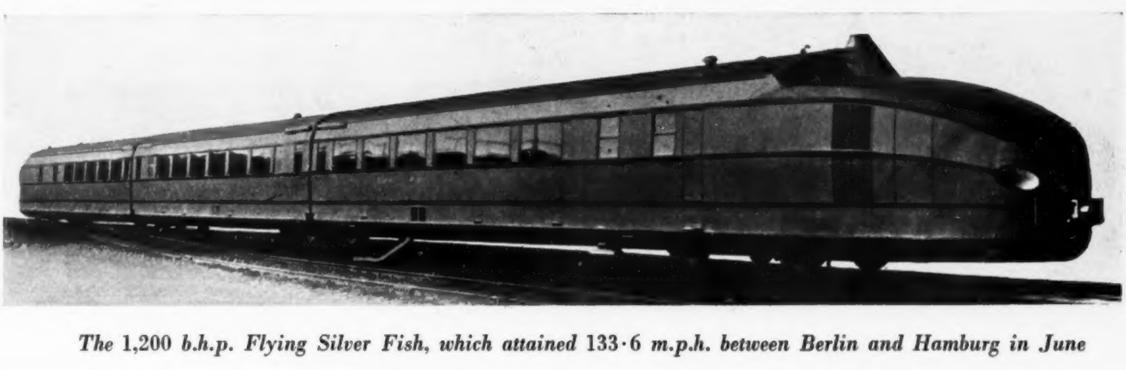
Two-power railcar for operation by diesel-electric propulsion or on direct electric traction from a 1,500-volt d.c. overhead supply. Two of these vehicles are at work in the Bordeaux area of the French National Railways. The diesel equipment comprises two 250 b.h.p. Alsthom-Ganz engines direct-coupled to 150-kW variable-voltage generators. Both engines are at one end of the car



One of two 1,200 b.h.p. diesel-electric locomotives used by the Swiss Federal Railways

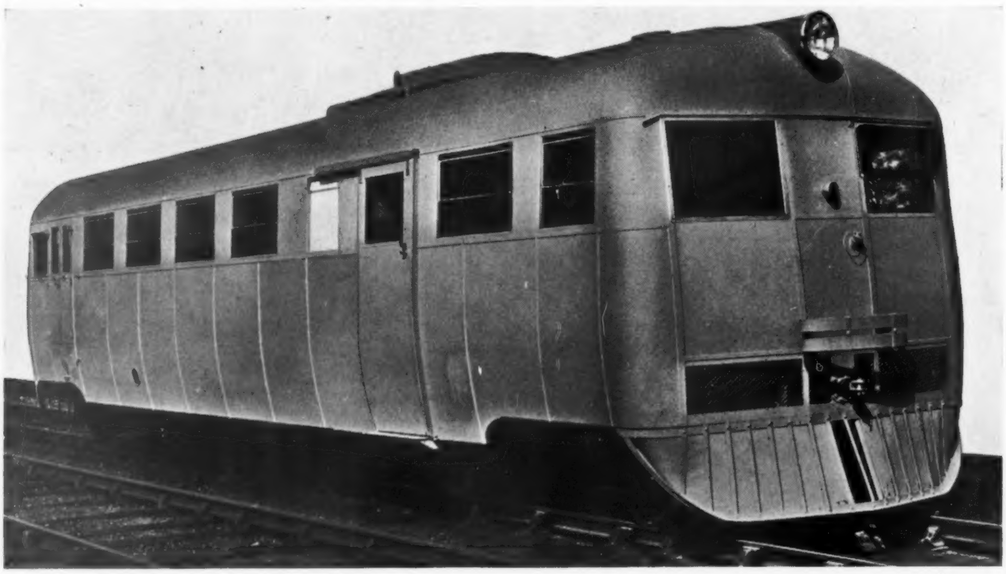


Schwartzkopff producer-gas shunting tractor operating on the Reichsbahn



The 1,200 b.h.p. Flying Silver Fish, which attained 133·6 m.p.h. between Berlin and Hamburg in June

600 *b.h.p. diesel-electric luggage van hauling special trailers, Algerian Railways*



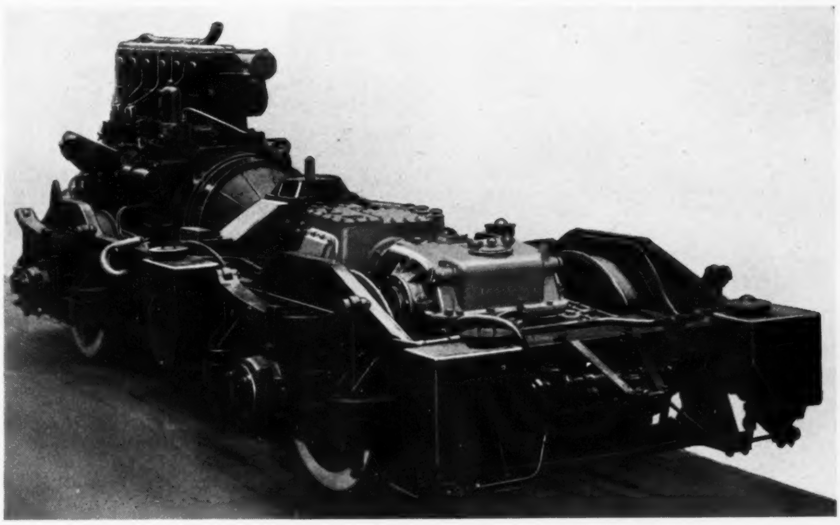
Double-engined 130 *b.h.p. Wickham railcar, Jamaica Government Railway*

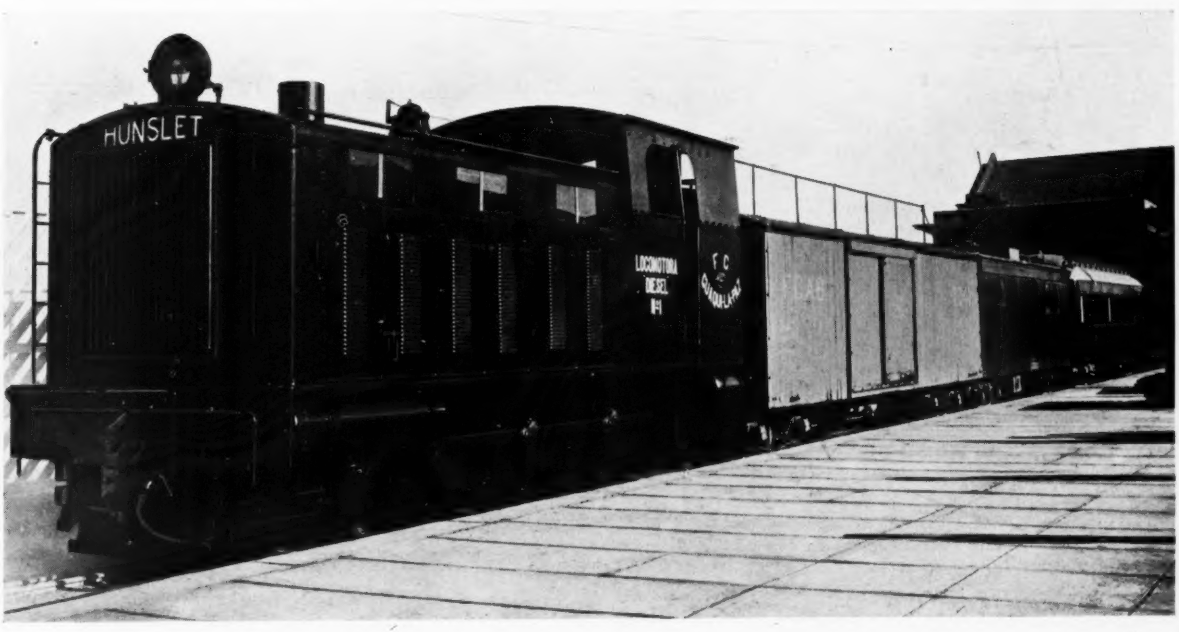
175 *b.h.p. double-engined air-conditioned Drewry car for the Nizam's State Railway*

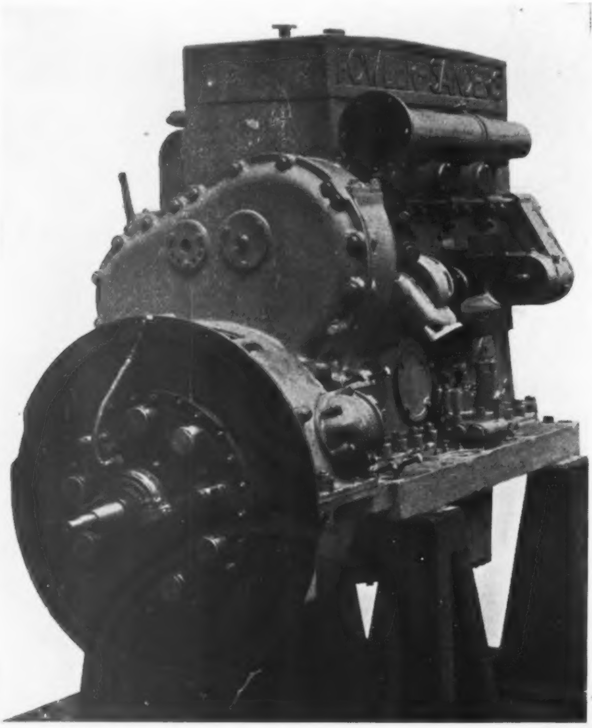
Above: Ganz car of 240 b.h.p. for the broad-gauge lines of the North Western Railway of India

Right: Drewry power bogie with Gardner engine, Vulcan-Sinclair fluid coupling and Wilson-Drewry gearbox, Tasmanian Govt. Railway

Below: The Hunslet pressure-charged 39-ton diesel-mechanical locomotive on the Guaqui-La Paz Railway

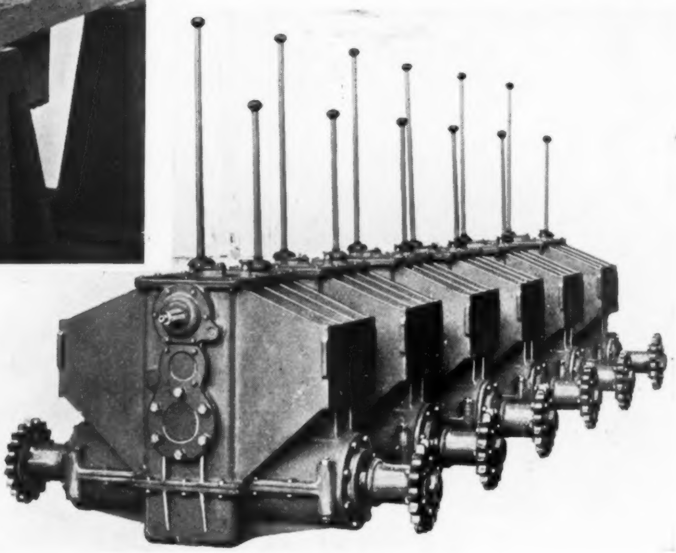




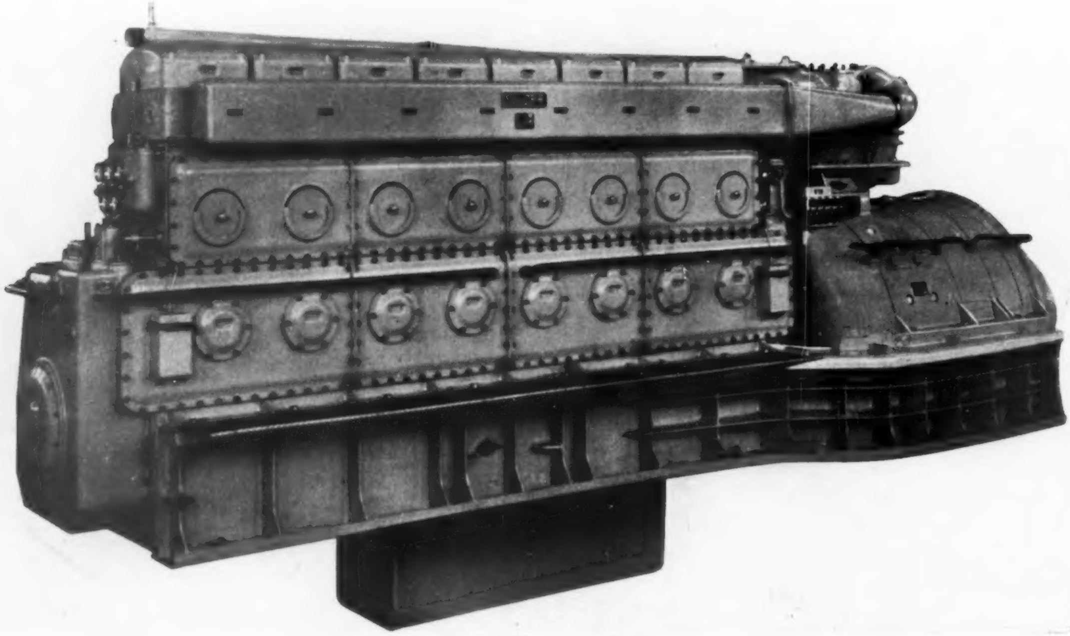


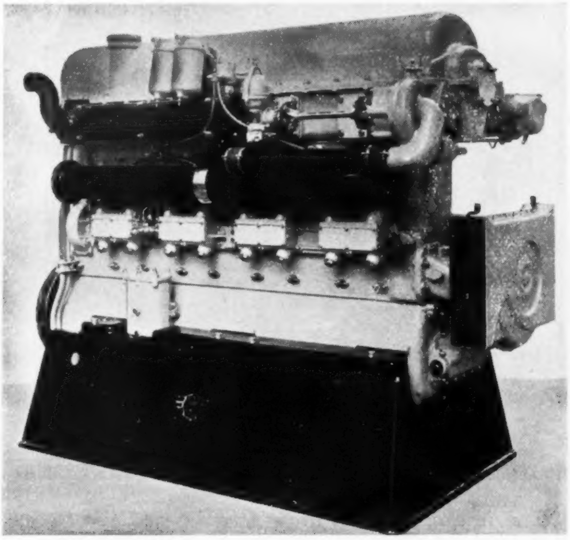
Left: A Fowler-Sanders two-way swirl oil engine, a large number of which were installed in Fowler shunting locomotives during 1939. The model shown develops 150 b.h.p. at 1,000 r.p.m. in four 7-in. by 9-in. cylinders

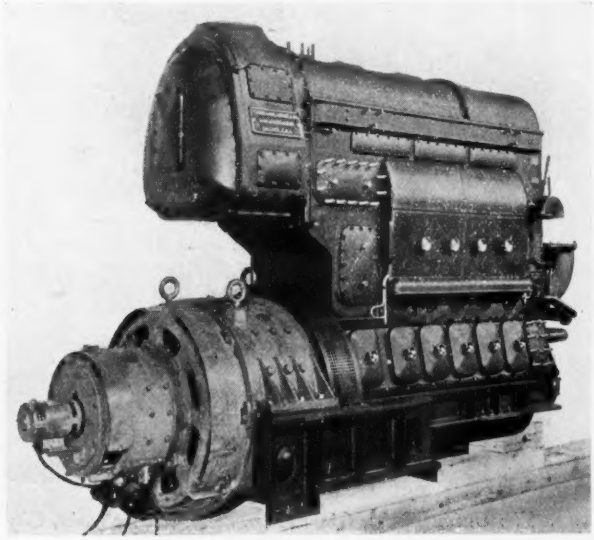
Below: Bostock & Bramley two-speed forward and reverse boxes installed, in conjunction with McLaren engines of 75 b.h.p., in a score of locomotives for the Egyptian Delta Light Railways



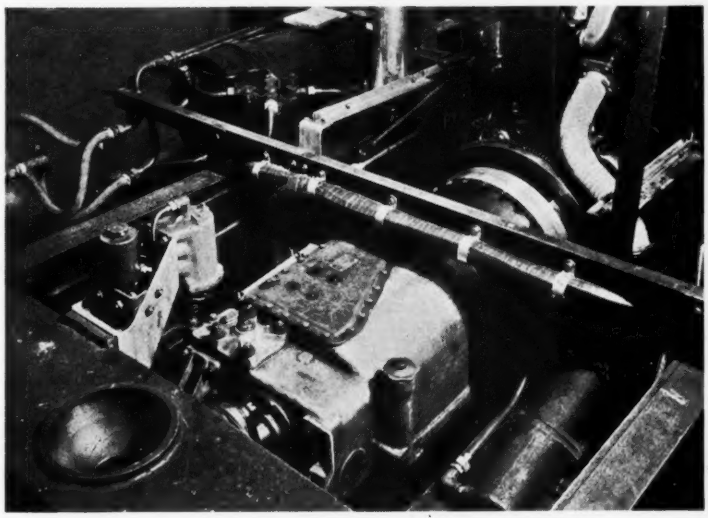
Below: New Sulzer eight-cylinder 1,200 b.h.p. locomotive oil engine with Büchi pressure-charger and Brown Boveri generator, supported on a common welded-steel underbed





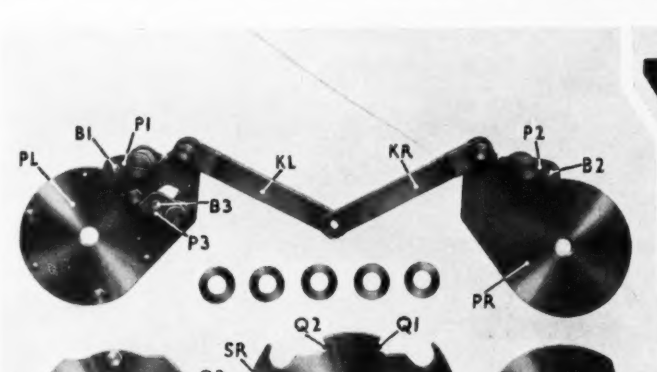


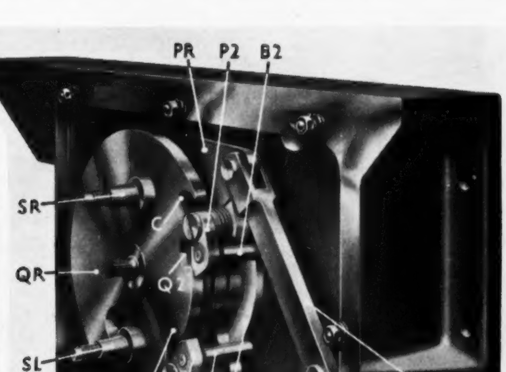
Above: Two new two-stroke opposed-piston engines: left, the 550 b.h.p. C.L.M.-Junkers model running at 1,500 r.p.m. and having a weight per b.h.p. of about 10 lb., and right, the American Fairbanks-Morse engine giving a maximum of 940 b.h.p. at 720 r.p.m. on a weight of 20·5 lb. per b.h.p.



Right: Part of a Walker power bogie for Peru, showing Gardner engine, Vulcan-Sinclair fluid coupling, and Wilson epicyclic gearbox

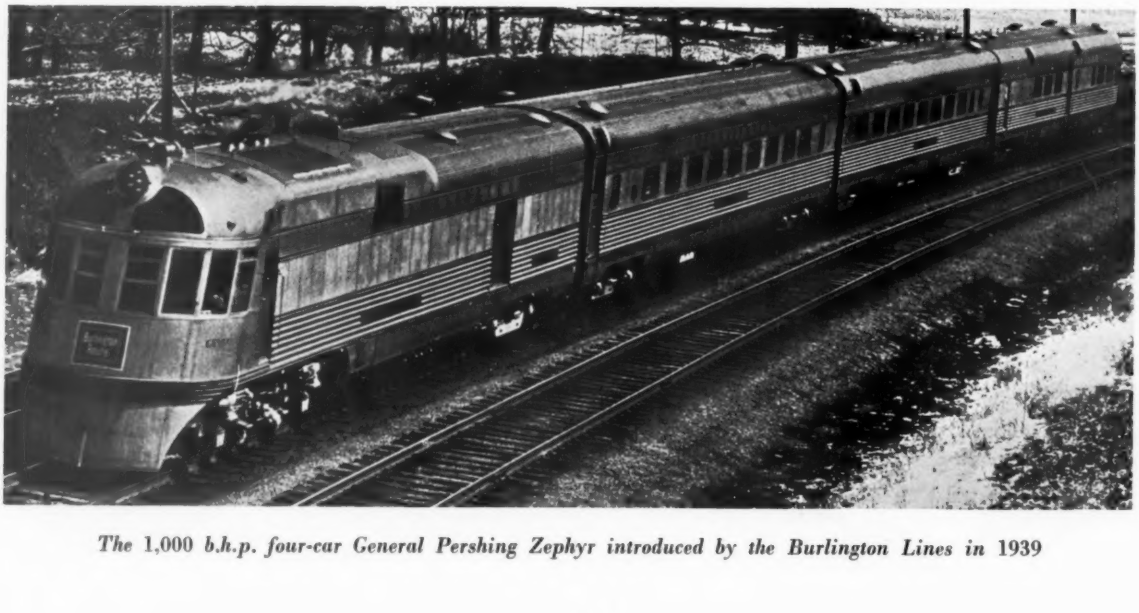
Below: The constituents of the ratchet and pawl mechanism of the Tele-change control used in conjunction with the Traction gearbox and Vulcan-Sinclair fluid coupling





The Union Pacific 6,300 b.h.p. diesel-electric train, City of Los Angeles. Another two of these 17-car Pullman trains, but with a 10 per cent. increase in engine power, were ordered during the year by the Union Pacific, Southern Pacific and Chicago & North Western Railroads

Diesel-electric rail-car of G.E.C. type pushing passenger car up the rack section of the Manitou and Pike's Peak Railway, which rises to a height of 14,110 ft. The power equipment comprises three engine sets each giving 100 b.h.p. at maximum altitude



The 1,000 b.h.p. four-car General Pershing Zephyr introduced by the Burlington Lines in 1939

to haul up to six ordinary coaches, giving a total seating capacity for the complete train of at least 600. Until the war the Lyntog sets were operating fast services and making a yearly mileage of about 147,000 per set, but at the beginning of the war the services were cut and the top speed lowered from 75 to 62 m.p.h. Since then the speed limit has been raised, and Denmark is now the only European country with more 60 m.p.h. bookings than before the war.

Italy

The railcar stock and railcar programme of the Italian State Railways are as large as those of any other railway system in the world, and when present construction is finished over 700 cars will be in traffic, of which about 80 per cent. will be diesel. An order for 100 cars placed a little over a year ago is being completed, but the cars are of a different type to the standard Fiat and Breda types built in large quantities between 1933 and 1938, being equipped with two Saurer-Brescia BXD engines of 150 b.h.p. In general, these vehicles are of a somewhat heavier design than the Fiat and Breda cars, and are fitted with the Lysholm-Smith form of partial-hydraulic transmission. The Fiat company is building the mechanical portions at Turin. Multiple-unit operation is possible, as in the standard Fiat and Breda cars. Delivery was completed during the year of 50 diesel-mechanical cars built by the Off. Mechaniche Milano, each powered by two 130 b.h.p. Brescia-Saurer engines. A further 30 Saurer BXD engines are on order for the Italian State Railways, but they are to be equipped with Büchi pressure-chargers.

Several Italian private railways continue to purchase diesel cars, principally of Fiat manufacture, in ones and twos, but since September much activity has been shown by the State lines and private railways in the use of alternative fuels, principally producer-gas from charcoal, and methane gas. Experimental running with both types of fuel is now under way in the Genoa, Milan, and Bologna areas.

The Balkans

Apart from Roumania, with well over 200 cars in local and express service, diesel traction has had but a spasmodic career in South-Eastern Europe. The Ganz triple-car narrow-gauge sets operating between Belgrade and Dalmatia have led to proposals to introduce standard-gauge main-line cars between Belgrade, Vinkovci, Zagreb, and Ljubljana; trials with Italian cars were made and end-to-end speeds of 50 m.p.h. shown to be possible over a line which at the moment has no steam schedules exceeding 40-42 m.p.h. Projects for increasing the small stock of Bulgarian railcars were drawn up during the year, covering the construction of four-wheel and bogie cars, but the war appears to have stopped orders being placed. Standard-gauge 800 b.h.p. twin-car diesel trains and 225 b.h.p. single-unit cars were ordered in Germany by the Turkish State Railways in 1938 and delivery of some of the stock was effected before September.

Norway

After operating but a handful of railcars for some years, the Norwegian State Railways began last year by ordering double-bogie cars, each with two D.W.K. eight-cylinder horizontal engines set to give 170 b.h.p. and driving through Lysholm-Smith partial-hydraulic transmission. In the late spring an order for four triple-car diesel-electric trains was placed, the sets being intended for fast passenger traffic on the Oslo—Bergen and Oslo—Trondheim lines, and eventually to run even further north, when the Bodö line is completed. At each end of a train there is to be the combination of a 12-cylinder Maybach engine and Büchi pressure-charger giving an output of 650 b.h.p., or a total of 1,300 b.h.p. for a 170-ton (gross) non-articulated train. The mechanical portions of trains and single-unit cars are being made in Norway by the Strømmens Verkstad A.B., but work in connection with the alternative form of diesel power for the Oslo—Bergen line, the 1,400 b.h.p. half of a diesel-hydraulic locomotive, is being carried out by Krupp, in Germany; Lysholm-Smith transmission and a pressure-charged M.A.N. engine are being installed. Yet a further solution of the Oslo—Bergen passenger traffic working, this time for tourist traffic only, was tried during 1939, in the form of a Michelin pneumatic-tyred car running three times weekly in each direction at a special fare, and making the journey of 306 miles in 8 hr. 38 min. including a stop for dinner. This particular car was rented for the summer season from the French National Railways, where it had worked on the Région du Sud-Est.

Sweden

Railcar stock in Sweden is made up principally of nearly 100 four-wheel and light bogie railbuses with petrol engines on the State and a few private lines, but since 1913 diesel cars have been used continuously, although in small numbers. Most of the up-to-date diesel vehicles are of Nydquist & Holm's Nohab type, with hydraulic transmission of the Lysholm-Smith pattern; a variety of engine makes is used, including the Hesselman type of low-compression oil engine. Both one- and two-engine designs of 100 to 250 b.h.p. are available in gauges of 35 in. to 4 ft. 8½ in., and there is also a range of the favourite Swedish adaptation, the eight-wheel locomotive with two driving compartments, an engine room, and a large luggage and parcels compartment. Twin-engine designs up to 480 b.h.p. are in use, and others up to 640 b.h.p. are available.

The bogie car built a year or two ago for the Uddevalla—Vanersborg—Herrljunga Railway, and powered by two of the new Atlas V engines mounted transversely on the bogies, has been rebuilt, and is now equipped with two Saurer BXD engines fitted with Büchi pressure-chargers to give 200 b.h.p. each. The original Asea electric transmission has been retained, but the engines and generators are now mounted longitudinally. Producer-gas propulsion is being given increased attention, and charcoal- or wood-burning plants have been applied to railcars and to shunting locomotives of the 12/20-ton class.

Other European Activities

Of all the diesel traction projects shelved as a result of the war, none was as great in magnitude as that which was to have been begun about the end of 1939 by the Polish State Railways, and which comprised the construction of railcars and railcar trains to the number of something like 300. In Switzerland, where the extensive electrification of Federal and private lines has left little scope for diesel vehicles, two very modern 1,200 b.h.p. double-bogie locomotives were acquired by the Federal Railways for hauling light passenger trains to accelerated schedules over the northern non-electrified lines, such as that from Basle to Schaffhausen. The eight-cylinder Sulzer engine is equipped with a Büchi pressure-charger and is mounted on the same base as a Brown Boveri main generator, which incorporates a special single-phase generator for providing current for the train heating system. A top track speed of 68 m.p.h. is permitted and the weight is only 65 tons. No railcars are yet at work in Portugal, the only European country which has not made use of diesel traction in one form or another; but enquiries for a selection of cars were made at the end of the year. The Hungarian State Railways, one of the cradles of diesel car operation, ordered only one new vehicle during the year—

another 275 b.h.p. Ganz Arpad express railcar, with a top speed of 75 m.p.h. when travelling over level track.

India

Just as big a potential market for railcars exists in India as in Africa, and it is not improbable that many of the small cars required will be built or adapted in the railway workshops in that country, and the engines and transmissions obtained from England. A car of this type is running on the Bikaner State Railway and is used for special chartered and excursion trips as well as in regular traffic. It is equipped with two Ford V8 engines—one at each end—and only one is in operation at a time; such an arrangement obviates any form of distant control in a dual-directional car, and the low cost of a Ford engine and its gearbox makes the layout a practical economic proposition.

Four vehicles of a much more grandiose character were built in England during 1939 for the Nizam's State Railway, and although not yet in regular service they were shipped from England before the end of the year. Of Drewry pattern, they comprise that firm's standard type of bogie with Gardner 6LW engine, Vulcan-Sinclair fluid coupling, and Wilson-Drewry epicyclic gearbox, but each bogie has a power plant, giving an aggregate output for the car of 204 b.h.p. at sea level but only 175 b.h.p. at the altitude at which they will work. Multiple-unit control is embodied, and this, along with the various engine, transmission, and auxiliary controls, incorporates improvements on the design used in the 99 B.A.G.S. cars of 1938. Complete air-conditioning of Stone's type is fitted although the cars are intended for native traffic only. These broad-gauge vehicles carry 84 passengers on a tare weight of 37 tons, and have a top speed of 50 m.p.h.; they are not equipped for trailer haulage.

Although delivery of the 11 Ganz cars of 240 b.h.p. to the North Western Railway began in 1938, no running was undertaken until 1939, and after numerous experimental trips in special service and on normal turns, a full service was begun in May in the Jullundur, Amritsar, and Lahore area. An aggregate mileage of about 77,000 a month was made for the first three or four months, but in November the cars were withdrawn from traffic for modifications to suit them more thoroughly to the conditions prevailing in the Punjab.

Burma and Ceylon

Four metre-gauge four-wheel petrol-engined railcars were put into traffic by the Burma Railways, on routes largely running parallel with roads. Ford V8 engines form the motive power, and the top speed allowed is 45 m.p.h. As a result of satisfactory operation of the three English Electric four-car diesel-electric trains on the Colombo outer suburban services the Ceylon Government Railway placed an order for eight single cars of English Electric manufacture, each of which is to have a 200 b.h.p. power plant similar to that installed at each end of the existing trains.

Africa

For years the majority of African railways have presented a vast potential field for diesel locomotives and railcars, but the surface has as yet been scarcely scratched. The principal service introduced during 1939 was between Constantine and Touggourt in Algeria, over which route the standard-gauge Michelin service from the town of Constantine to Biskra, is continued by metre-gauge diesel-hauled trains comprising a 600 b.h.p. De Dietrich diesel-electric baggage car hauling two or three special trailers. The complete three-car train tares 69 tons. The time for the 135 miles from Biskra to Touggourt has been cut by more than three hours as a result of replacing steam traction by diesel. The car bodies are welded up of chrome-copper steel, and the bogies have shock absorbers.

Further inaugurations and extensions of diesel locomotive working were made in other French colonies, notably in Madagascar and on the Dakar-Niger Railway, but also on the island of Réunion, and the first railcars in the Belgian Congo were set to work on the Katanga lines. On the Eritrean, Abyssinian and Tripolian railways Fiat cars and a Fiat-engined locomotive were put into traffic.

Several orders of direct English interest were placed by African organisations during 1939. First, the Egyptian Delta Light Railways, after trial with one or two light units, decided to adapt or build in their own works the mechanical portions of a score of small diesel locomotives, and for installation ordered 20 McLaren oil engines of 75 b.h.p. and 20 sets of mechanical transmission comprising Bostock & Bramley two-speed forward and reverse gears. These locomotives are being used for both passenger and freight trains over 0·75-metre gauge lines. Three lightweight double-bogie cars with Büchi-pressure-charged Saurer engines of 200-220 b.h.p. were ordered from Wickham by the Kenya & Uganda Railways; the pressure-charger is fitted to enable the necessary engine power to be maintained up to an altitude of over 7,000 ft. above sea level. Within a car length of 51 ft. are being provided six first class and 52 native seats, and this on a tare weight of about 20 tons. These cars will run over metre-gauge lines.

Two important orders for the Ganz type of vehicle were under prosecution during the year, the first, comprising a dozen single-unit cars of 320 b.h.p., for the 3 ft. 6 in. gauge lines of the South African Railways: the second consisting of two twin-car 480 b.h.p. and two single-unit

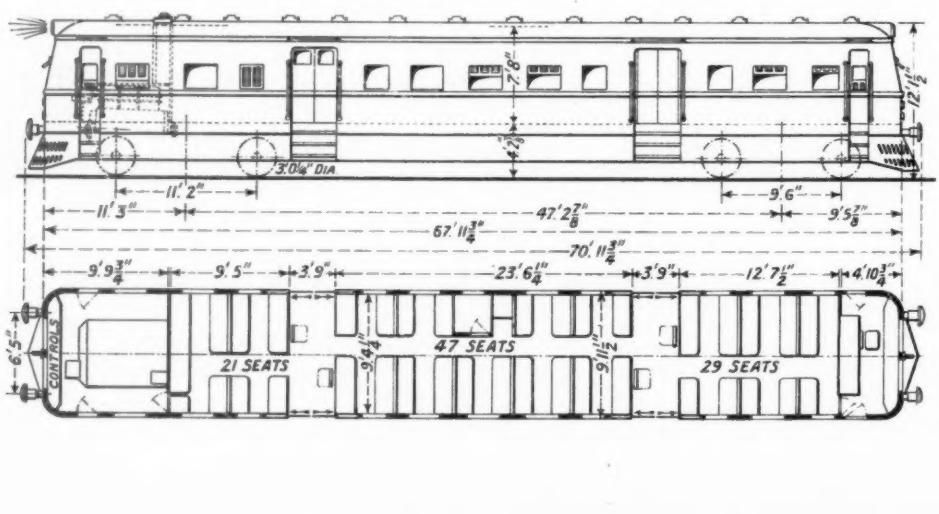
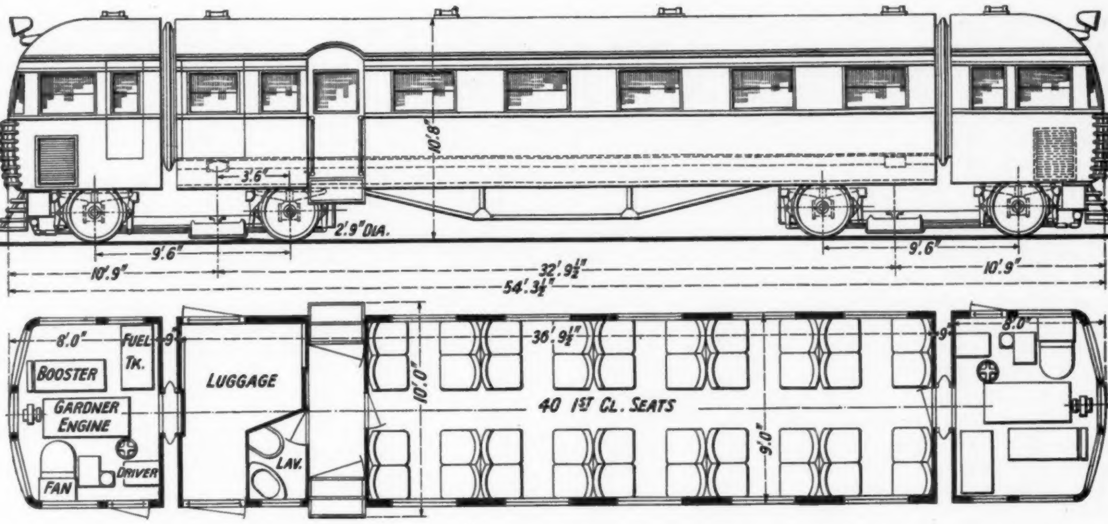


Diagram of one of the eleven 100-seater 31-ton Ganz diesel-mechanical railcars introduced on the broad-gauge section of the North Western Railway of India. The engine and transmission are mounted on one bogie, and the other bogie is a trailer



The Walker double power bogie 200 b.h.p. railcar for working over the Central Railway of Peru; mechanically-driven blowers are fitted to keep the engine output constant from sea level up to 16,000 ft.

240 b.h.p. cars for the same gauge of line on the Rhodesian Railways; both orders were placed with the Metropolitan-Cammell Carriage & Wagon Co. Ltd.

The Orient

Several cars, multi-car trains, and locomotives powered by oil engines were set to work in Japan, and further diesel-mechanical cars of French manufacture were sent to Indo-China. After much contemplation, the Netherlands East India State Railways placed an order with Beijnes, of Haarlem, for three triple-car diesel trains with mechanical transmission for main-line service. The engines are to be of the Thomassen type with Büchi pressure-chargers, and the two engines in each train are to have an aggregate output of 600 b.h.p. The transmission will comprise S.L.M.-Winterthur gearboxes and Vulcan-Sinclair fluid couplings. Seats for 110 passengers are to be provided in these 3 ft. 6 in. gauge trains. Following tenders received from all over the world, the Thailand State Railways placed an order with Sulzer Bros., of Winterthur, for several diesel-electric locomotives.

Australasia

Several new oil-engined railcars and more conversions of petrol cars to diesel power were recorded on the Queensland Government Railways, and there is talk of converting the whole of the extensive stock of light petrol cars to oil-engine power. Most of the cars are of 50 to 100 b.h.p. and haul special light trailers on the many up-country lines and on others nearer the coast. Recent railcar activity in New South Wales has been concentrated on very small and light four-wheelers seating 18 to 20 passengers and powered by petrol engines, but the 720 b.h.p. diesel-hydraulic trains continued to give good service on the Broken Hill route.

After making several conversions from petrol to diesel power in the course of a couple of years, the Tasmanian Government Railway acquired four cars of 100 b.h.p. and two of 150 b.h.p., all of pleasing appearance and sound design. The bodies were built in New South Wales, but the complete bogies were supplied from England by Drewry, and carry the usual Gardner engine, Vulcan-Sinclair fluid coupling and Wilson-Drewry gearbox combination. The cars tare 19¾ tons and haul special trailers seating 62 passengers on an empty weight of 10 tons. The 1937 order for six twin-engined railcars was completed early in 1939 by the New Zealand Government Railways, the mechanical portions being built in the Hutt Valley workshops; the 130 b.h.p. Leyland engines and Lysholm-Smith (Leyland) hydraulic transmission were sent out from England. These cars appear to have given quite good results on a variety of services, principally in North Island. The diesel-mechanical cars of 275 b.h.p. ordered complete from England have not yet been delivered.

South America

As usual, the Latin-American countries held a good deal of the diesel stage. Deliveries exceeded the new orders placed, mainly on account of the growing tension throughout the world during the first half of 1939. The principal order of the year was that for 10 triple-car 640 b.h.p. diesel-mechanical trains and seven 240 b.h.p. single-unit cars placed by the Argentine State Railways with Metropolitan Railcars (Ganz Patents) Limited, the vehicles all to be built at the Budapest works of Ganz. This order, valued at approximately £300,000, will bring the number of Ganz diesel vehicles on the A.S.R. up to 143, trailers in twin-car and triple-car trains being counted as separate diesel vehicles. Delivery of Ganz diesel cars from previous orders was completed during the year.

The last of the 99 Drewry cars for the B.A.G.S. was also delivered and put in traffic during the year; many of these cars are working on the Buenos Aires outer suburban services but numbers are at work further out on the system and on the associated B.A. Western lines. On the B.A. Midland Railway the 10 twin-car 200 b.h.p. diesel-mechanical trains built by the Birmingham Railway Carriage & Wagon Co. Ltd. in 1938 were introduced into intensive service. An important shipment from Europe towards the end of the year comprised 12 Ganz double-bogie 275 b.h.p. diesel-mechanical railcars for the broad-gauge lines of the B.A. & Pacific Railway, these being developments of the three diesel-mechanical and three diesel-hydraulic railcars of the same make set to work in the Mendoza area about two years ago.

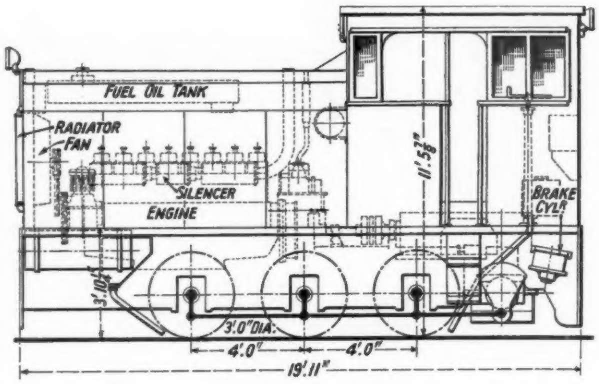
At long last the two four-car 600 b.h.p. Armstrong-Whitworth diesel-electric *de luxe* trains were shipped to the São Paulo Railway, and in the early autumn were set to work on regular schedules between Santos and São Paulo, being raised and lowered by cable on the Sierra incline, the equipment of which, incidentally, limited the

length of the train to 195 ft. and the weight to about 108 tons without passengers. The train is single-end drive only, and the front power car accounts for 47½ tons of the total weight. The engine is the Armstrong-Sulzer 6LDA25 type, fitted with a Büchi pressure-charger, and is set to give a maximum of 600 b.h.p. at 750 r.p.m.

Further north in Brazil, the two 450 b.h.p. English Electric diesel locomotives built in 1938 operated with a train of specially built passenger coaches over the metre-gauge lines of the Eastern Railway. The Central Railway, which in 1937 had in view the eventual use of about 30 main-line diesel locomotives, during 1939 proposed to purchase three main-line sets of about 1,400 b.h.p., but the European war apparently has caused the project to be shelved for the time being. The five Fiat twin-car 290 b.h.p. trains delivered to the Central Railway in 1938 were not introduced to regular service between Rio, Sao Paulo, and Bello Horizonte, until the beginning of June, 1939, operation being delayed on account of adjustments and negotiations on certain technical and monetary matters.

Pacific Seaboard Countries

Most interesting technical developments were pursued on several of the Peruvian and Bolivian lines belonging to the Peruvian Corporation. For example, the electrified Guaqui-La Paz Railway, with grades as steep as 1 in 14, took delivery of a 240 b.h.p. Hunslet diesel-mechanical locomotive, pressure-charged in order to maintain a reasonable engine output at the site altitude of 10,000 to 13,395 ft. above sea level. It is not impossible that the results given by this locomotive will cause electrification to be abandoned, for the equipment introduced when the line was converted in 1905 is now obsolete and worn out, and new stock will in any case be needed shortly. The locomotive weighs 39 tons, and the four-speed Hunslet mechanical transmission gives track speeds of 5, 7½, 11, and 16 m.p.h. with corresponding tractive efforts of 15,500, 10,300, 7,000, and 4,800 lb. Very complete starting and braking equipment is included to cope with the great altitude and exceptionally steep adhesion grade. Other Hunslet locomotives supplied during 1939 to the Peruvian Corporation included a 23-ton six-wheel unit with a 165 b.h.p. McLaren engine for the Piata-Piura

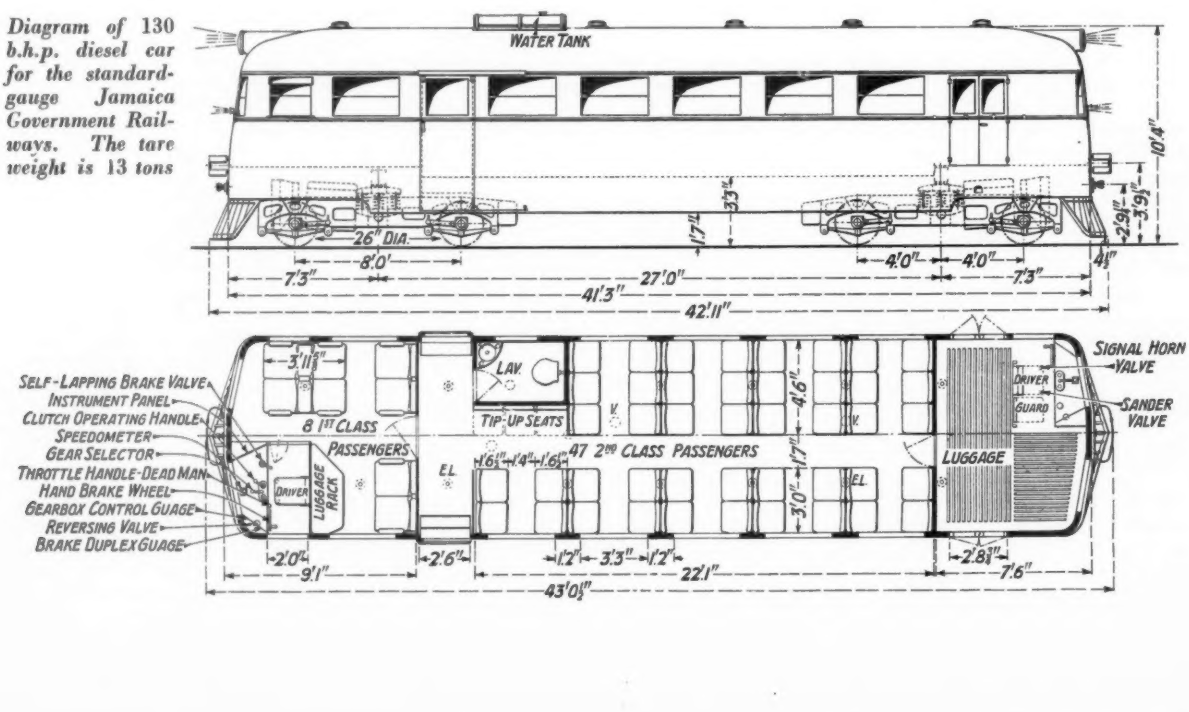


Hunslet 165 b.h.p. diesel locomotive for the Piata-Piura Railway

Railway and an 82 b.h.p. locomotive for the Chimbote line.

Railcar traction was confined, as far as new construction was concerned, to the Central Railway of Peru, although an order for one car was placed in England by the Trujillo Railway. A stage in the development of the standard Walker car was reached with a double power bogie vehicle with Walker's own form of mechanically-driven pressure-charger designed to maintain the engine output as nearly constant as possible on the run from Callao to Galera and Oroya, that is, over an altitude ranging from sea level to 15,800 ft. This 24-ton vehicle has two Gardner 6LW engines driving through Vulcan-Sinclair fluid couplings, Wilson five-speed gearboxes, and Layrub cardan shafts. Westinghouse compressed air and Metro-Vick electromagnetic track brakes form part of the equipment. Following experience with a steam car rebuilt with diesel motive power, the Central of Peru placed orders for ten Saurer BXD engines pressure-charged on the Büchi system to give sea-level outputs of 200 to 220 b.h.p. and a maximum-altitude output of 160 b.h.p. Five of these engines will replace the steam motive power in Sentinel railcars, and five are for installation in new cars

Diagram of 130 b.h.p. diesel car for the standard-gauge Jamaica Government Railways. The tare weight is 13 tons



designed to run up to a height of 15,000 ft. over the 75 miles of 1 in 22-25 leading from Lima to Galera summit. The original Saurer-engined Wickham bogie installed in the old Sentinel railcar No. 5 covered 33,800 miles in the first six months of its service, but has not maintained such a mileage since.

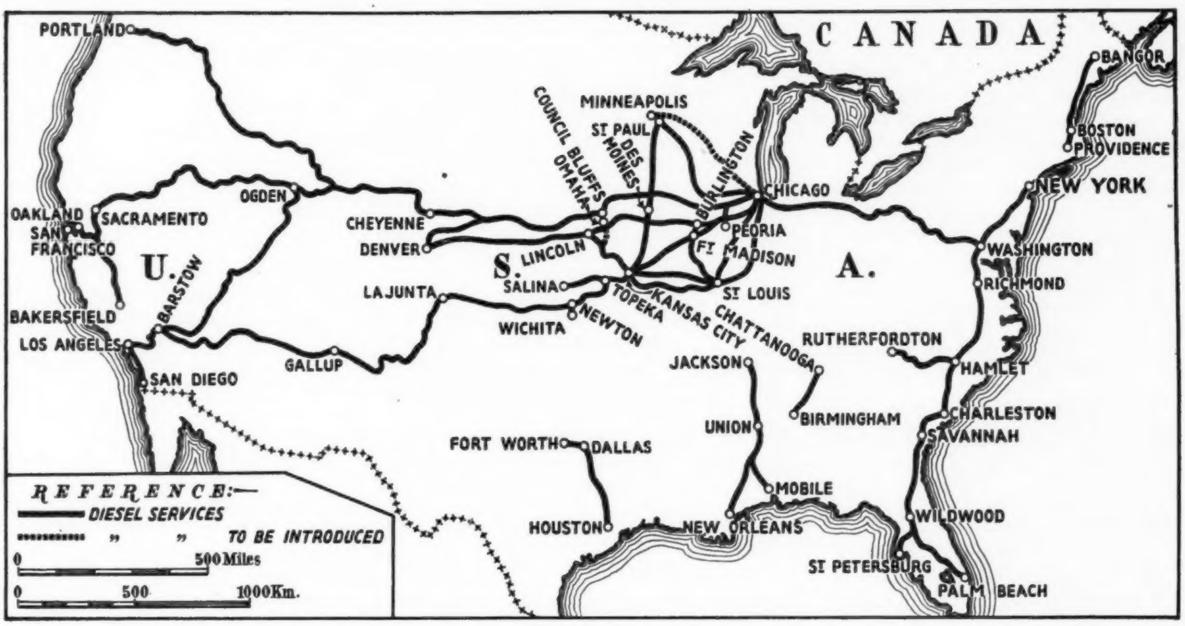
West Indies

Apart from minor rebuildings from petrol to diesel in Cuba, the only event of the year was the completion in England of the first of three light railcars for the Jamaica Government Railway—the first cars to be used by that system. Built by Wickham, of Ware, the first car has Mylius gearboxes, but owing to the war the boxes for the other two cars could not be obtained, and therefore Cotal electromagnetic gearboxes are being substituted. Power is provided by a Perkins P6 engine carried on each bogie, and set to give 65 b.h.p. at 1,750 r.p.m. A total of 55 passengers in two classes can be seated, but for tourist traffic the 47 second class seats can be removed easily and replaced by a score of lounge chairs and three tables. The top speed is normally 45 m.p.h., but on test in Jamaica the first car attained 55 m.p.h., presumably downhill, and traversed 300-ft. curves at 35 m.p.h.

U.S.A.

Diesel traction business in the United States during 1939 must have amounted to about £6,000,000, divided almost equally between deliveries and orders placed. Beginning with the Seaboard Air Line's Silver Meteor on February 2, a total of 18 streamlined diesel-electric trains was placed in service, the figure excluding such seasonal trains as the Seaboard's Orange Blossom Special, which ran in the preceding year. Apart from these set trains, other high-power locomotives were built, including four of 4,000 b.h.p. (traction power) and 20 of 2,000 b.h.p. In addition, 180 diesel-electric switching and freight-transfer locomotives of 300 to 2,000 b.h.p. were delivered for home service, and nine up to 1,000 b.h.p. were exported.

That pioneer high-speed line the Chicago, Burlington & Quincy, introduced yet another Zephyr, the *General Pershing*, which since April 30 has operated between St. Louis and Kansas City; this is a four-car train powered by the new 1,000 b.h.p. General Motors two-stroke engine developed from the earlier 900 b.h.p. model by opening out the cylinder bore from 8 in. to 8½ in. The morning Twin Zephyr service was speeded up to cover the 431 miles between Chicago and St. Paul in 6¼ hr., an average of 69 m.p.h. and including intermediate start-to-stop speeds as high as 78 m.p.h. The fastest point-to-point timing of the Denver Zephyr is the 97 min. for the 124·6 miles between Galesburg and Aurora, equal to 77·1 m.p.h. By December 31 the nine Zephyr trains in service had made an aggregate mileage of 8,312,362, over which the availability has been 96·4 per cent.



Map showing lines over which high-speed diesel services were in operation in the U.S.A. in the summer of 1939

During 1939 the Burlington placed extensive orders for new diesel equipment, including five 600 b.h.p. switchers and seven 2,000 b.h.p. main-line locomotive units. Four of the 2,000 b.h.p. sets will be operated singly or in multiple-unit as required; the other three will be run only in conjunction with units of the first type to make a 4,000 b.h.p. locomotive; all the wiring connections are arranged so that any number of the first or second type of unit can be worked by one man in the front control cabin. Two 4,000 b.h.p. combinations are to be used to haul the Exposition Flyer between Chicago and Denver, and another 4,000 b.h.p. combination and the remaining 2,000 b.h.p. single unit are to be used in general utility service, handling main-line passenger trains.

Extensive diesel haulage of the New York to Florida trains was adopted by the Seaboard Air Line in 1939, three seven-car Silver Meteor trains being introduced, and nine 2,000 b.h.p. Electro-Motive locomotives being acquired to haul them and the Cotton States Special, and to supplement the sets working in triple-unit formation on the winter-only Orange Blossom Special. The locomotives of this type weigh 147 to 152 Engl. tons. The new twin-car diesel trains of the Southern Railway are not engaged in high-speed working, but the success of the Seaboard trains led the competing route to Florida—the Atlantic

Coast and Florida East Coast lines—to purchase three diesel-hauled trains, each with a 2,000 b.h.p. locomotive. The former owns two of the units and the F.E.C. one, but the F.E.C. also acquired a second seven-car diesel-hauled train to run between Jacksonville and Miami. All the above Florida trains are worked between New York and Washington by Pennsylvania electric locomotives.

One of the most important diesel inaugurations of the year was the Chicago & North Western's 400, operating between Chicago and the Twin Cities in competition with the Twin Zephyrs of the Burlington and the steam-hauled Hiawatha of the C.M. St. P. & P. Hitherto the 400 had been worked by steam, but on September 24 two new 10-car trains each hauled by a twin-unit 4,000 b.h.p. double-end drive diesel locomotive were put into traffic on schedules containing intermediate start-to-stop speeds as high as 75·8 m.p.h. The principal remaining high-speed diesel service of 1939 was the Rocky Mountain Rocket of the Chicago, Rock Island & Pacific Railroad, running between Chicago, Denver, and Colorado Springs; each of the two 10-car trains is hauled by a 2,000 b.h.p. locomotive, compared with the 1,200 b.h.p. units of the earlier Rocket trains, such as the Peoria Rocket. Although the Santa Fe did not introduce any further high-speed train equipments, it acquired a 4,000 b.h.p. locomotive to act as spare, and also put into traffic 26 diesel switchers of 1,000 b.h.p., the 13 with Alco engines being pressure-charged on the Büchi system.

Other 2,000 b.h.p. diesel locomotives were supplied to the Kansas City Southern and the Missouri Pacific for passenger traffic, and two for short-distance freight transfer service were ordered by the Illinois Central. The Union Pacific, whose City of Denver train makes the fastest start-to-stop run in the U.S.A.—81·4 m.p.h. over the 62·4 miles between Grand Island and Columbus—ordered, in conjunction with the Chicago & North Western, another City of Los Angeles diesel train with 14 revenue cars and three power cars, and in conjunction with the C. & N.W. and Southern Pacific another train of similar formation to run between Chicago and San Francisco, to replace the City of San Francisco train so badly damaged in the accident at Humboldt River on August 12. In each case the traction power will be increased from 5,400 to 6,000 b.h.p. compared with the older trains by the use of the new General Motors 1,000 b.h.p. engine, and the total installed power including the auxiliary sets will be 7,000 b.h.p.

American Switching Locomotives

The majority of the shunters were Electro-Motive 600 and 1,000 b.h.p. standard models, but other types were the Alco 660, 900 and 1,000 b.h.p. standards, the last two with pressure-chargers; G.E.C. locomotives of 1,000 b.h.p. with two Cooper-Bessemer engines; and, from 150 to 500 b.h.p., G.E.C. locomotives with Cummins engines. Baldwin built a total of 28 diesel-electric locomotives of 660 and 1,000 b.h.p. to its new standard design, and these were intended primarily for stock, so that quick delivery could be given to any customer; locomotives of the 1,000 b.h.p. type were delivered to the Missouri Pacific and Santa Fe lines. De la Vergne six-cylinder and eight-cylinder locomotive oil engines are used in the two sizes, and are characterised by very large cylinders, *viz.*, 12¾ in. by 15½ in.; the rotational speed is 625 r.p.m. A Baldwin non-standard delivery comprised seven 660 b.h.p. eight-wheel rigid-frame locomotives to the Texas Mexican Railway, and these will eventually operate all the traffic on the system. An American export order of interest was the first of five 1,000 b.h.p. diesel locomotives built for the Panama Railroad by G.E.C., and geared for a top speed of 70 m.p.h., and another comprised two G.E.C. double-bogie locomotives for Mexico.

Engines and Transmissions

New engine types were not numerous during the year, and from a technical point of view interest probably centred upon the two opposed-piston two-stroke engines, the C.L.M.-Junkers 550 b.h.p. and Fairbanks-Morse 940 b.h.p. models. Normally, the French engine is set to give 500 b.h.p. at 1,500 r.p.m., and in its design is much the same as the earlier 250 b.h.p. size which has been described already in these pages. The Büchi system of exhaust-gas turbo pressure-charging continued to make progress, and orders for 165 sets for a total engine output of approximately 100,000 b.h.p. were placed for rail traction purposes during 1939; the output per engine varied from 200 to 2,000 b.h.p. Among the more popular engine makes, the Renault has now reached a total of 620 engines aggregating 168,700 b.h.p., the Ganz to 799 engines totalling 162,000 b.h.p.; the Maybach to 800 engines aggregating 330,000 b.h.p. (and including 550 engines of the 12-cylinder V type); and the Saurer to 897 engines totalling 141,000 b.h.p.; all of these figures include railway engines built by the makers' licensees. What may perhaps in future years be regarded as the outstanding oil engine event of 1939 was the commercial application of the Kadenacy principles to two-stroke engines, giving appreciable increases in performance and probably a longer engine life without the addition of expensive extraneous details.

Several interesting transmission applications or proposals were made during the year, including the Freeborn and Traction gearboxes, the Synchro-mesh transmission, the metadyne electric system, and the first hydraulic transmission for a diesel locomotive in the U.S.A. Work was also carried out on a 1,400 b.h.p. set of Lysholm-Smith hydraulic transmission and on automatic clutch operation in mechanical transmission.

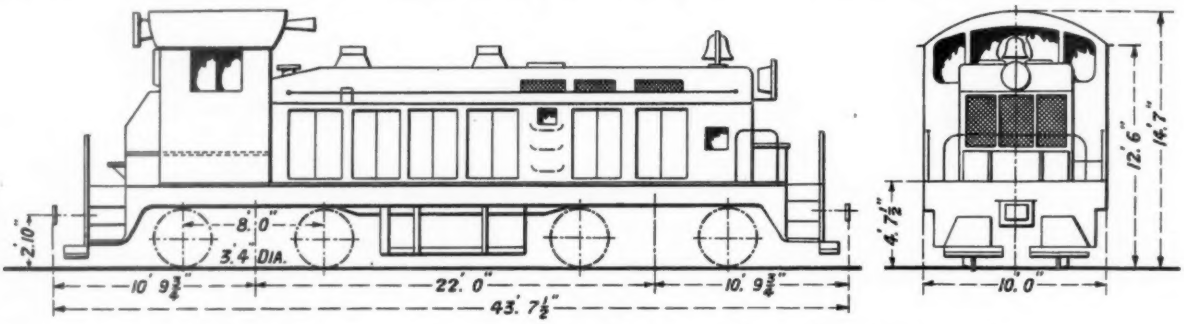


Diagram of the Electro-Motive standard 900 b.h.p. diesel-electric switching locomotive

Diesel Railway Traction

Herbert Akroyd Stuart

FEW people in these days believe the story of James Watt and the kettle, but 55 years ago the accidental spilling of oil from a paraffin lamp led to a train of thought in the mind of Herbert Akroyd Stuart which resulted eventually in the heavy oil engine as we know it today. Stuart's first important patent was not taken out until 1890, and to commemorate the jubilee of the crucial period of his work, as well as to give recognition to the work he did, the Diesel Engine Users Association on January 11 held an Akroyd Stuart lunch, followed by a paper on the inventor and his work compiled by Messrs. T. Hornbuckle and A. K. Bruce. Slightly ante-dating Diesel in his ideas, and by some years in the production of commercially-successful engines, Stuart introduced the features of injecting the fuel into the air near the end of the compression stroke, ignition being achieved by the heat of compression. A vaporiser was used to vaporise the fuel, thus supplying some of the heat needed to give certain ignition, and enabling ignition to be obtained with a moderate compression pressure. The injection equipment was of the airless type, and naturally was of crude construction; it was unsuitable for working in conjunction with high compression. Stuart made use of an antechamber, the forerunner of modern precombustion chambers rather than of the air-cell or dual-turbulence heads adopted so extensively in modern high-speed designs, and he appears to have been fully aware of the combustion control which such an arrangement gave over a wide range of engine load and speed. Although Stuart was not the first man to draw attention to the possibilities of compression ignition, there is little doubt that he was the first to construct an engine along these lines, and, in association with Richard Hornsby & Sons, of Grantham, to make a practical success of it.

American Streamliner Speeds

THE speed performance of the express diesel trains in the U.S.A. has long been of a high order, and for some time included a run by the Super-Chief timed at over 83 m.p.h. start-to-stop. After decelerations, this run fell below one or two of the German *Schnelltriebwagen* journeys, and the fastest diesel run in the States for some time has been the 81·4-m.p.h. schedule of the Union Pacific's City of Denver train between Grand Island and Columbus, a distance of 62·4 miles. Recent accelerations of the Twin Zephyr trains of the Chicago, Burlington & Quincy Railroad to an end-to-end average of 71·9 m.p.h. over the 431 miles from Chicago to St. Paul include a start-to-stop run scheduled at 39 min. for the 54·6 miles between E. Dubuque and Prairie du Chien, corresponding to an average speed of 84 m.p.h., and the fastest regular diesel run ever scheduled. The previous timing was equivalent to a speed of 78 m.p.h. Another intermediate timing on this trip is 44 min. for the 58·6 miles from La Crosse to Prairie du Chien, an average of 79·9 m.p.h. In the summer of 1939 American diesel trains were running 16,023 miles a day at start-to-stop speeds of a mile-a-minute or more, of which 3,284 miles were booked at 70 m.p.h. or over and 1,064 at 75 m.p.h. or more. In this total the City of Denver claimed the two fastest runs, viz., 81·4 m.p.h. from Grand Island to Columbus, and 80·3 m.p.h. from North Platte to Kearney, 95 miles in 71 min. The third run was the 155-min. booking of the Santa Fe's Super-Chief and El Capitan trains over the 202·4 miles from La Junta to Dodge City, equal to 78·3 m.p.h., and actually a deceleration of the 146-min. booking of the Super-Chief when the present equipment was introduced two or three years ago.

Diesel Traction and Speed

FOR the past seven years the fastest start-to-stop run in the world has been accomplished by diesel power, and, indeed, in each year from 1934 onwards the great majority of all runs timed at 70 m.p.h. or more have been in the hands of oil-engined locomotives, train sets, and railcars. On the basis of the summer timetables for 1939, diesel traction was responsible for 67 per cent. of all runs at 70 m.p.h. or over, and for 97 per cent. of those at 75 m.p.h. or more. In 1933 the Flying Hamburger initiated a new era of speed with bookings of 76-77½ m.p.h. between Berlin and Hamburg. Apart from a brief period when the American Santa Fe Railroad's Super-Chief train was timed at 83·3 m.p.h., the blue riband of railway speed has been held consistently by the *Schnelltriebwagen* of the German State Railway from May, 1933, until the beginning of the war. For several years the top speed has been in excess of 80 m.p.h., and in last summer's timetable was 83·3 m.p.h., the Fliegende Kölner taking only 79 min. for the 109·7 miles from Hamm to Hanover. Seven other start-to-stop runs at speeds in excess of 80 m.p.h. were made each day by Reichsbahn diesel trains, the longest being over the 157·9 miles between Berlin and Hanover. All ten daily runs made throughout the world in 1939 at 80 m.p.h. or more were in the hands of diesel units, and of these Germany claimed eight and the U.S.A. two. At 75 m.p.h. and over there were 33 runs in Germany and 17 in the U.S.A.; the fastest in any other country with railcar traction was the 73-m.p.h. trip between Nancy and Paris, but this was operated by a Bugatti petrol-engined car. Taken over the whole world, in the summer timetables of 1939, diesel traction was responsible for a daily mileage of 34,155 at start-to-stop speeds of a mile-a-minute or more. Of this total, 16,023 miles were in the U.S.A., 8,321 in Germany, and 3,147 in Holland; by reason of the drastic decelerations of all forms of traction since the formation of the French National Railways, the total for France was only 3,006 miles. Of the diesel grand total, 16,044 miles were run at schedule speeds of 66 m.p.h. or more, compared with 8,862 miles by steam and 7,157 miles by electric traction.

HIGH-POWER MAIN-LINE LOCOMOTIVES IN THE U.S.A.

A description of the mechanical portions of seven 2,000 b.h.p. diesel-electric units now under construction by the Electro-Motive Corporation for express haulage on the Burlington Lines

THE Chicago, Burlington & Quincy Railroad, which operates nine Zephyr trains varying in output from 600 to 3,000 b.h.p., ordered towards the end of last year seven 2,000 b.h.p. locomotive units for hauling the Exhibition Flyer between Chicago and Denver and for general utility service on high-speed main-line passenger trains. In January the tenth Zephyr, comprising four revenue cars hauled by a 2,000 b.h.p. locomotive unit was ordered for service between Lincoln and Kansas City and two further eight-car trains are to be ordered shortly for operation between Denver, Fort Worth, and Dallas, Texas. The Exhibition Flyer will be handled by two 2,000 b.h.p. locomotives coupled in multiple unit, and the Texas Zephyrs will be hauled by a 4,000 b.h.p. power unit. Of the seven 2,000 b.h.p. sets ordered in 1939, four are "A" units which can be operated singly when any particular duty requires only 2,000 b.h.p. The three remaining sets are termed " B " units and can be used only when coupled to one of the "A" locomotives, so that a total of 4,000 b.h.p. is available for handling long and heavy trains driven by one man. The connections are so arranged that any number of " A " and " B " sets can be coupled together in multiple unit.

Driving and Non-Driving Units

All seven locomotives of the 1939 order will be equipped with two 1,000 b.h.p. engine-generator sets mounted within a single body which is to be carried on two six-wheel trucks, each of which will be equipped with two traction motors geared direct to the end axles. The general locomotive design will be suitable for negotiating 250 ft. radius curves at slow speeds in sidings. In fully loaded condition the weight of an "A" unit will be approximately 310,000 lb. and of a " B " unit 301,000 lb. The tanks in each unit have a capacity of 1,200 U.S. gal. and the amount of boiler water is 1,050 U.S. gal. in the "A" unit and 1,200 U.S. gal. in the " B " unit. The overall length of the twin set giving 4,000 b.h.p. will be 140 ft. 4 in., almost equally divided between the two sets. The overall width is to be 9 ft. 10 in., and the height from the rail to the top of the carlines 13 ft. 11 in. Wheel and wheelbase particulars are given on the diagram accompanying this article.

Body Frame

The design of the body framework simulates bridge construction and the side frames will be in the form of a modified Howe truss calculated to carry the entire body weight and superimposed load; the effect of the side panels is not included in the stress calculations. The power equipment is to be carried principally on the frame cross members and the centre sill sections interposed between these cross bearers, in effect, will be continuous, and will be expected to take all the buffing and draw stresses. The upper members of the side frames are to be tied together by roof members and the roof sheets themselves will be attached to closely-spaced carlines. Whenever possible, the construction is to be of rolled steel sections in order to ensure straightness, but where the sections intersect the longitudinal members will be attached to large diamond-shaped gussets so that the transfer of the loading forces is gradual. Particular care is being taken to avoid abrupt changes of section which might result in stress concentrations. The welded bolster and cross bearer assemblies are being stress-relieved before being built into the car structure. The portion of the underframe projecting beyond the bogie pivot at the front end is to be fabricated with top and bottom cover plates extending between the side sills and designed to form a rigid box platform. End frame posts, spaced approximately in line with centre sills, join the platform and roof structures.

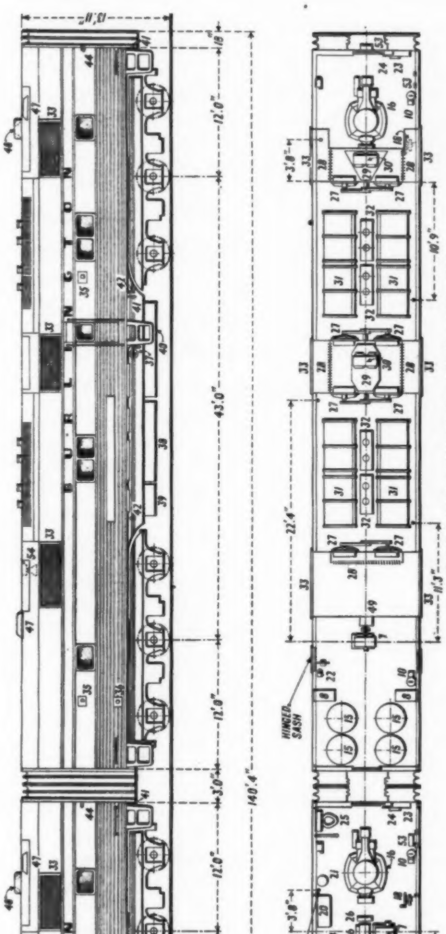
Four jacking points are to be provided along each side of the locomotive unit, with 7-in. pads at each end of the bolsters and additional pads between the centre plates. All are located approximately 46 in. from the rail. The fabricated steel roof hatches are to be covered by stainless steel sheets and will be removable for the installation or removal of engines, generators, steam boilers, and other equipment. The hatch framing is to form a convenient support for the engine cooling radiators while at the same time providing a deep truss frame adding to the roof strength. Lifting eyes are to be provided on each hatch.

Stainless Steel Panelling

The outside of the locomotives is to be coated entirely in stainless steel except for the steps and the window sashes. The thickness will vary from 14 gauge on the roofs to $\frac{3}{16}$ in. for the front members. Above the side sills the panelling is to be of the Budd fluted stainless steel type, including filler strips, name board, and end pieces. The panelling between windows and between the air intake grilles is to be of plywood panels with an exterior sheathing of 24-gauge steel and an interior sheathing of Galvanneal steel with soldered edges as a protection against moisture. All other panelling on the side frames is to be against impregnated canvas backing to prevent frictional wear of the metal covering. Space is provided in the panels for batten holding bolts to permit uneven expansion and contraction of the metals.

The grilled air intake above the cab ceiling at the front end, which is customary in the Zephyr trains, is to be omitted in view of the position of the radiators, but an imitation grille is to be substituted to preserve the appearance of the standard Zephyr front end. These imitation grilles are to be arranged to act as covers for the electric train-line jumper boxes.

An indirectly illuminated instrument panel is to be located in the driving position and will house the usual air brake gauges, speedometer, and wheel slip indicator. An additional speedometer instrument is to be mounted externally adjacent to the standard panel, and the auxiliary instrument panel carrying the fuel and boiler-water gauges will be located directly in front of the assistant driver's position, which is to the left-hand side of the cab. Motor-driven windshield defrosters are being fitted to the front windows. They will receive hot, dry air from steam-heated coils mounted on the cab floor directly in front of the driving position and the coils themselves are to be fed through Vapor low-pressure reducing valves independently controlled and terminating in a conventional steam trap. The front windows are to be of $\frac{5}{16}$ in. safety plate glass and are to be equipped with windshield wipers having individually controlled valves. The cab side windows are to be of $\frac{1}{4}$-in. safety plate glass arranged



PLAN VIEW WITH ROOF AND FALSE CEILING REMOVED

PLAN VIEW WITH ROOF ONLY REMOVED

1—Engines—E.M.C., 1,000 b.h.p.
2—Generators
3—Aux. generator
4—Controller
5—High & low voltage cabinets
6—Air compressor
7—Traction motor blower
8—Sand boxes
9—Operators' cab
10—Fire extinguisher
11—Control valve
12—Engine control & instrument panel
13—Load regulator resistor panel
14—Load regulator
15—Boiler water tanks
16—Clarkson boiler
17—Engine fuel pumps
18—Hand brake
19—Fuel tank vent with flame arrester
20—Lubricating oil tank
21—Water treatment tank
22—Hostler's control
23—Boiler control panel
24—Signal lights
25—Toilet
26—Fan drive
27—Fans
28—Shutters
29—Engine cooling water tank
30—Lubricating oil cooler
31—Radiators
32—Exhaust manifold
33—Cooling system air intake
34—Horns
35—Sand box filler
36—Boiler water filler
37—Fuel filler
38—Batteries
39—Tool box
40—Fuel tank
41—Engine water filler
42—Lub. oil drain
43—Classification flag bracket
44—Flag & lamp bracket
45—Classification light
46—Speedometer
47—Air vent
48—Boiler stack
49—Distribution cabinet
50—Boiler water & fuel gauges
51—Instrument panel
52—Electrical coupler
53—Portable back-up light
54—Bell
55—Locker
56—Reversible shutters
57—Mars signal light
58—Uncoupling lever

so that the rear portion may drop into a pocket and provide a 19-in. opening; the forward portion of the side windows is to be pivoted for adjustable ventilation. Three rubber-cushioned swivel seats with arm and back rests are to be fitted in the cab, the floor of which will be wood covered and overlaid with brown linoleum. The cab ceiling and parts of the side walls are to be insulated with 2 in. Rockwul covered with $\frac{1}{16}$-in. acoustical steel flashing. The side doors in the cab will have adjustable drop windows and, like the side panels, are to be covered with stainless steel.

Stainless steel $\frac{3}{16}$ in. thick is to be used also for the cowcatcher which will be securely bolted along the top and well braced between the chord members and the underframe platform. The braces will be readily detachable by removing accurately-fitted large-diameter pins which will be cottered in position. Projecting from the locomotive front platform will be a solid steel buffer to match the diaphragm buffers on standard rolling stock. On each side of the buffer will be the usual fluted anti-telescoping device consisting of stainless steel angles bolted to the underframe platform. Both front and back automatic couplers are to have rubber draw springs and the conventional uncoupling device will be fitted at each side.

Pipe and Jumper Connections

At the front end of the A-type locomotive units the trainline connections will provide for emergency or permanent applications of the brake pipe, air signal, straight air and steam hose connections. All air and steam lines at this point will terminate in pipe couplings and plugs with suitable self-locking cut-out cocks and a steam cut-off valve. Due to the necessity for the A locomotives to operate back to back, duplicate angle brackets are to be provided at the rear end on each side for the hose connections, supplementary to the usual brake pipe and signal lines, such as straight air, application and release, main reservoir equalising pipe and special sander control. Only one set of hose is to be supplied and the duplicate angle bracket will be plugged. Connections for the front end of the B unit will be duplicates of those provided for the rear end of the A type, except that no provision is to be made for dual hose connections. The connections at the rear end of the B unit will be duplicates of those provided at the front end, except that the special sander control hose will be omitted.

Both front and rear of A and B units are to be equipped with power-plant control and air brake control electrical trainline jumper receptacles. The plugs and receptacles for these two controls will be different, in order to preclude the possibility of improper coupling. The A unit is to have power plant and air brake cables with 16-point plugs. The B units are to be equipped with only the air-brake control jumper with 16-point coupling. This will be fitted to one end only; the other end will be left open to receive the air-brake control coupler furnished with the leading car of the streamlined trains.

Bogies

The two trucks are to be identical and the assemblies will be interchangeable between No. 1 and No. 2 positions when applied in the reverse direction. The truck frame is to be supported on four points by twin group coil springs which will ride on four equalisers carried between journals. Swing bolsters will be supported at each corner by a pair of fully elliptical springs which will ride on each end of the two spring planks, these in turn being carried by hangers pivoted outside the truck frame. Hydraulic shock absorbers will be fitted to damp out bolster oscillations. The two end axles of each truck are to be motored, but the centre axle will be a carrier and is necessary only

for load carrying and braking purposes. The weight of the truck assembly, including two traction motors, will be approximately 50,000 lb. All trucks are to be fitted with a stainless steel skirt bolted in place with the minimum number of bolts and divided in sections to permit of ready removal. Suitable cut-outs are to be provided for getting at the slack-adjuster mechanism and for the inspection of brake cylinder piston rods. Apart from this skirt, the trucks and the underneath equipment generally are to be painted aluminium.

The 36-in. wheels are to be spread over a bogie base of 14 ft. 1 in., and are to be forced on standard axles with 6½ in. journals, but modified to suit the oversize gear and wheel seats. The axles are to be supported on Hyatt roller bearings which will include a spring cushion lateral thrust arrangement. The centre axle of each truck is to be equipped with a special box suitable for receiving either the Decelostat for the braking, or the speedometer magneto. The axlebox guides are to be fitted with manganese steel roller plates bolted to the cast nickel steel truck frame. Although the centre plate of the truck pivot will be of large diameter, the truck bolster is to be extended above the centre wheels to provide the usual friction type of side bearer. Combined with these side bearings will be interlocks between the truck and the body, and which incidentally stop the truck slewing in a derailment.

Brakes

Westinghouse air brake equipment is to be provided and will incorporate graduated control whereby the braking percentage will be reduced with the reduction of speed when making a stop. The brakes are to be applied by four 11-in. cast-iron cylinders per truck, which will apply the blocks through clasp rigging. With a 7·3 to 1 leverage and 100 lb. cylinder pressure, the braking force is to be approximately 190 per cent. of the tare weight, or 180 per cent. of the weight in full running order. All the brake pins and bushings are to be hardened and ground; the casehardening is to be carried out to double the customary depth, and the pins themselves are to be oversized in order to reduce wear. The brake piping is to be entirely of copper. Under each car body are to be mounted two 24½ in. by 66 in. main reservoirs made of Cor-ten steel with riveted seams and welded heads. The compressed air on each 2,000 b.h.p. unit is to be supplied by two Gardner-Denver two-stage air-cooled compressors with a displacement of 89 cu. ft. per min. at 800 r.p.m. Air cooling is to be provided by 12 ft. of finned copper tubing and 25 ft. of plain tubing between the compressor and the first main reservoir. Automatic and manual air sanding is to be applied to the leading wheels of each truck. The automatic feature comes into operation with every emergency brake application. Selective sander control is to be omitted so that the driver may have individual control of the equipment on the A and B units, but this control will not affect the automatic feature from all sand traps in the event of an emergency brake application.

Power Equipment

Power in each locomotive unit is provided by one of the standard General Motors two-stroke V engines developing 1,000 b.h.p. at 800 r.p.m. in a dozen 8½ in. by 10 in. cylinders. Each engine will have a separate water circulation system, comprising two engine-driven water pumps with an individual capacity of 200 U.S. gal. a minute and forced air circulation through Harrison fin-tube radiators. For each engine there is to be provided a separate water supply tank with a capacity of 90 U.S. gal., and provision is to be made for steam-jet heating of the cooling water during lie-over periods. The air delivery per engine through the radiators will approximate to 60,000 cu. ft. per min., and the draught is to be provided by four 26-in. fans belt-driven from the main engines. The air delivery to the radiators of the A-type locomotive units will be controlled by reversible shutters mounted on the roof above the radiator assemblies. In the B-type units the shutters are to be mounted in the air intake ducts, but in both types of locomotive the shutters will be operated automatically by thermostats with electro-pneumatic control. A 1,200 U.S. gal. fuel tank is provided for each engine, filling connections being provided on each side of the locomotive and arranged for a 4 in. Protectoseal element with a 2½ in. fuel connection. The tank is to be fitted with a bottom sump, cleanout plug, and non-removable water drain. The fuel system itself is to be of the return flow type and will include one motor-driven pump per engine. This pump will be fitted with a Purolator screen filter of 0·003 in. mesh in the suction line.

Electric Transmission

The engine is to be coupled direct to a 600-volt d.c. main generator, the voltage of which is to be controlled by a load regulator. A 10-kW auxiliary generator is to be carried above the main machine and driven from it by V belts. It will be capable of use as a battery-charging unit with a tension adjustable between 74 and 78 volts. Two traction motors will operate in conjunction with each power plant, each force-ventilated from an engine-driven blower delivering 2,000 cu. ft. of air per min. per motor. The air is to be directed to the motors through openings in the bolster and body centre pivot plates, and from the bolster to the hollow truck transoms through machined openings. The passages between swing bolster and transom are to be sealed by special gaskets and steel wear plates, and from the transom to the motors the air will go through flexible rubber tubing.

High-voltage control arrangements will provide for automatic forward transition of motor connections between series, parallel, and shunted field. Backward transition is to be automatic between shunt and parallel and manual between parallel and series. The switch equipment for the transition of the output from a single generator to its pair of traction motors is to be arranged in individual ventilated cabinets and all high-voltage circuits are to be safeguarded by a ground protective relay. The low-voltage control includes in each locomotive unit a distribution cabinet containing the main fuse, fuse test blocks, battery cut-out switch, battery charging ammeter and voltmeter, individual switches and fuses for the independent control of the steam boiler, air brake, power-plant control, and lighting. Two control cabinets in each locomotive unit will house the battery charging voltage regulator, ammeter, reverse current relay, contactor, load fuse, cut-out switch, generator shunt and battery field contactors and resistors, and the starting contactors for the motoring generator. An Exide Iron-clad 32-cell battery is to be carried.

Train Heating

Steam for the heating of the locomotive and the train is provided by a Clarkson-type boiler manufactured by the Vapor Car Heating Company, and which will have an evaporative capacity of 2,250 lb. an hour at 225 lb. pressure and which will be complete with a three-cylinder belt-driven feed water pump driven direct from the fuel pump. Other equipment includes automatic fire ignition, two 1¼-in. pop safety valves, a stop valve, a pressure gauge reading to 400 lb., a train line pressure gauge reading to 300 lb., strainers, and water softener. The boiler water supply capacity is to be 1,200 U.S. gal. per locomotive unit, carried in four cylindrical tanks mounted upright at the No. 1 end of each unit. The tanks are to be equipped with steam-jet heating for lie-over purposes.

FRENCH DIESEL SHUNTING LOCOMOTIVES

Improved design of shunter, capable of hauling 700 tons up 1 in 72 at 4½ m.p.h. on the one-hour capacity, and of quick manœuvring in passenger stock yards, has a maximum axle load of 17 tons

635-b.h.p. 65-ton shunter of the French National Railways

BETWEEN 1933 and 1935 the then P.L.M. Railway put into traffic round the Gare de Lyon in Paris four heavy double-bogie diesel-electric locomotives, which performed the passenger shunting in the station and hauled empty stock to and from the sidings at Conflans. After observing the behaviour of these units an order for three further locomotives was passed, and delivery taken in 1938 and the early part of 1939. The new locomotives embody certain modifications, principally the provision of a single cab near the centre of the length; a pressure-charged engine; improved fuel feeding arrangements; simplified electric transmission without automatic regulation and with an optical and acoustical load indicator in the cab; and the ability to feed the traction motors from a battery and work the locomotive to the depot at slow speed if an engine failure should occur. Normally the locomotives are at work for 22 hr. a day for six days a week and for 16 hr. on the seventh day.

Mechanical Portion

Body, frame, and bogies are built up of welded steel plates, those forming the bogie frames being one inch thick. The longer of the two end compartments contains the engine-generator set and certain auxiliaries; the shorter bonnet houses electric control apparatus and the battery. Traction motor blowers, the compressor, and the engine water pump are located in small side casings. The interior of the cab is heated by radiators fed with hot water from the engine cooling system.

The 44-in. wheels are spread over a bogie wheelbase of 8 ft. 2½ in., and the axles are carried in grease lubricated plain bearings supported by overhung laminated springs composed of 16 plates 4·35 in. wide by 0·474 in. thick, and with a deflection of 0·266 in. per *tonne*. Curves of 395 ft. radius can be traversed with a gauge widening of ½ in. A pneumatically-operated device is incorporated in the bogies for use when the tractive effort is equal to or more than 25 per cent. of the weight, and limits to 8 per cent. the alteration in weight due to the torque reaction through the motor nose. The bogie has a hemispherical pivot and lateral control springs set to give an initial load of 2,050 lb. Automatic and variable Westinghouse air brakes apply blocks to all wheels, and a hand brake actuates the blocks on the bogie nearest the cab. A modern type of air sanding equipment is fitted.

Engine and Transmission Equipment

Power is provided by a Sulzer six-cylinder four-stroke engine, type 6LDA25, equipped with a Rateau exhaust-gas pressure-charger. In accordance with normal Sulzer practice, the engine framework is built up by a combination of steel castings and welded steel plates, and along with the directly-driven main generator and overhung auxiliary generator, is mounted on a single welded steel underbed. The cylinders have a bore of 250 mm. and a stroke of 320 mm., and including the pressure-charger and the oil pump the engine weighs 6 tons. The electric control gives four speeds and four outputs when the engine is operating pressure-charged and a further four combinations without pressure-charging. These are shown in the accompanying table.

The eight-pole self-ventilating main generator is of Jeumont manufacture. It has a continuous output of 355 kW at 355 volts 1,000 amp. when turning at a speed of 695 r.p.m. and a one-hour capacity of 352 kW at 315 volts and 1,120 amp. when turning at 815 r.p.m. The overhung auxiliary generator is of the six-pole self-ventilating type with a continuous output of 40 kW at 170 volts and 235 amp. when running at 695 r.p.m.

Each axle is driven by a force-ventilated nose-suspended

SULZER ENGINE OUTPUT

Output	B.H.P.	R.P.M.
Pressure-charged		
One-hour	635	815
Continuous	550	695
Reduced output	410	575
Minimum notch	300	460
Without pressure-charging		
One-hour	385	840
Continuous	330	715
Reduced	275	595
Minimum notch	220	485

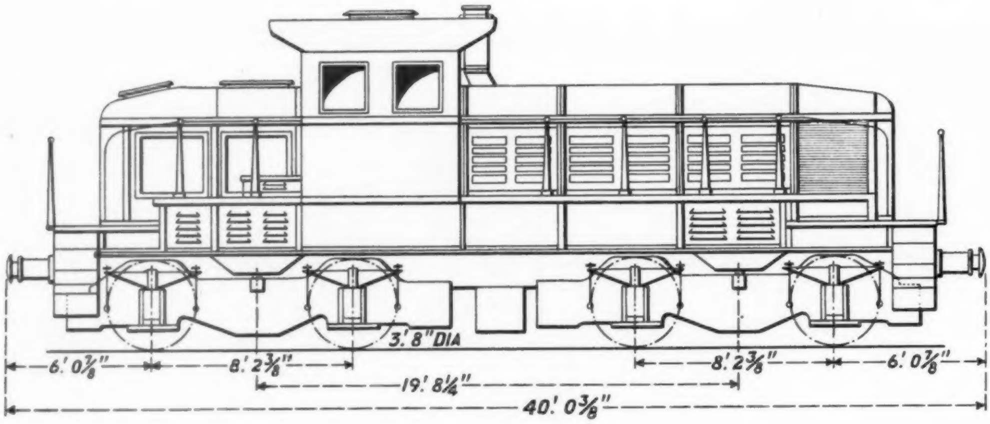


Diagram of the Sulzer-engined 635 b.h.p. diesel shunting locomotives with simple electric transmission built for the ex-P.L.M. Railway, France

motor through single gears with a ratio of 1 to 3·65. Each four-pole motor has a continuous output of 89 kW at 355 volts and 250 amp. and a one-hour capacity of 88 kW at 350 volts and 280 amp. The two motor-blower groups are of small size and require a total of only 4 h.p.

Electro-pneumatic contactors are used for starting up the diesel engine and for the control of the main and auxiliary generators, traction motors, and auxiliaries. Other electrical equipment includes an electro-pneumatic reverser, four cut-out switches for the traction motors, overload relays for the traction motors, and the usual Sulzer electro valves for the starting and speed control of the diesel engine. A hand-operated switch is incorporated to enable the locomotive to be worked from the battery. The cadmium nickel battery is of the Tudor type with 90 cells and a capacity of 218 amp.-hr.

The complete engine equipment weighs 6½ tons and the electrical equipment 18 tons; added to the 40½ tons of the mechanical portion, this gives a total tare weight of 65 tons. The weight of the supplies totals 3 tons, of which both fuel oil and sand account for one ton. The maximum axle load is a shade over 17 tons and the differences in axle load between the front bogie and the back bogie is merely of the order of a quarter of a ton.

Early Railcars in the U.S.A.

By E. F. WEBER, Superintendent of Automotive Equipment, Chicago, Burlington & Quincy Railroad

THE first passenger railcar on the Burlington Lines was built in the shops at Aurora, Ill., during the year 1898. The prime mover was a Cornell three-cylinder four-stroke gasoline engine with cylinders 10 in. bore by 12 in. stroke, which delivered approximately 100 b.h.p. at 240 r.p.m. This engine weighed about 12,000 lb.; the flywheel alone weighed 5,000 lb. After various tests it was found that the engine caused so much vibration that it was physically impossible to keep the various parts and chain-driven transmission intact.

The Wilmerding Engineering Company, who directed the installation, then attempted to reduce the vibration by adding more counterbalance to the crankshaft which in the final stages weighed 1,944 lb. Even then the terrific detonation, due to inadequate cooling and poor combustion, caused cylinder heads, valves, and pistons to break in a very short time; in fact, these parts would get so hot that the best metal available at that time would warp, crystallise, and fail before a round trip of approximately 90 miles was completed. At that time the lightweight, high-speed, internal-combustion engine had not been perfected, so after many discouraging failures and heavy expenditure the experiment was discontinued.

Meantime the McKeen railcar was being developed, using a three-cylinder 125 b.h.p. vertical-type gasoline engine, direct connected to the transmission by a chain drive. Later, in 1905, the General Electric Company built some passenger railcars, using an eight-cylinder V-type gasoline engine which developed 175 b.h.p. at 550 r.p.m. and weighed 7,350 lb., or 42 lb. per b.h.p. As far as I know, these were the first gasoline-electric railcars manufactured in the U.S.A., and quite a number are still in service.

In the year 1922 the Burlington Lines again became interested in passenger railcars in order to reduce the operating costs in branch-line service. The first seven of these cars had straight mechanical drive, the performance of which was quite satisfactory when the car was operated by the same engineer. However, when any of these cars were placed in a pool where another driver from a steam train had to complete the run, the performance was rather discouraging. During this experiment it was shown that mechanical transmission for a railcar weighing over 30,000 lb. was not the most economical, even though the first cost was considerably less than for the conventional electric power unit, which provided the essential flexible means for transmitting power from the engine to the rails.

These cars proved that an attractive saving over steam train service could be made in branch-line operation; therefore fifteen 275 b.h.p. gasoline-electric railcars were purchased from the Electro-Motive Corporation and placed in service during 1927. The performance of these cars was so successful that 42 additional cars were bought and placed in traffic during the years 1928 and 1930, replacing 192 steam locomotives, all of which were retired and scrapped after inauguration of gasoline-electric passenger railcar services. The saving over steam train operation amounted to 31·8 per cent. on an investment of $2,290,295.

During the early part of 1933, the Burlington management gave serious consideration to the construction of a three-car, lightweight, streamlined, stainless-steel high-speed train, and eventually put into traffic the Pioneer Zephyr, which was followed by a further eight trains ranging from 600 to 3,000 b.h.p., all of which have been dealt with in previous issues of this Supplement, and which up to the end of 1939 had covered an aggregate mileage of 8,312,362.

ENGLISH-BUILT RAILCAR FOR TASMANIA

Well-known design developed to suit specialised-traffic vehicle for operation on 3 ft. 6 in.-gauge private railway

TWO types of service conditions, differing to the maximum possible extent, are to be met by a double-bogie railcar just shipped by Walker Bros. (Wigan) Limited to the Emu Bay Railway, in Tasmania. In summer the car is to be used for high-class tourist traffic, and for that purpose the interior is provided with extremely comfortable seats and is decorated and fitted in a manner which is luxurious without being ostentatious. When not engaged in this traffic the car is to be used for the conveyance of industrial workers to and from their work, and the accommodation in relation to this purpose is of an excellent character.

In its essentials the car is the Walker standard type, with articulated power bogie housing the complete motive power plant and the driving cab; single-end drive; and an underframe clear of all auxiliary and brake apparatus. The tare weight is 18½ tons. Trailer haulage up to a weight of about 17 tons is contemplated, and at the back end the car is fitted with a central door to enable the guard to pass to and from the trailers. A top speed of 40 m.p.h. is allowed. There are no particularly sharp curves on the line, but the railway rises to a height of 2,300 ft. above sea level.

Engine

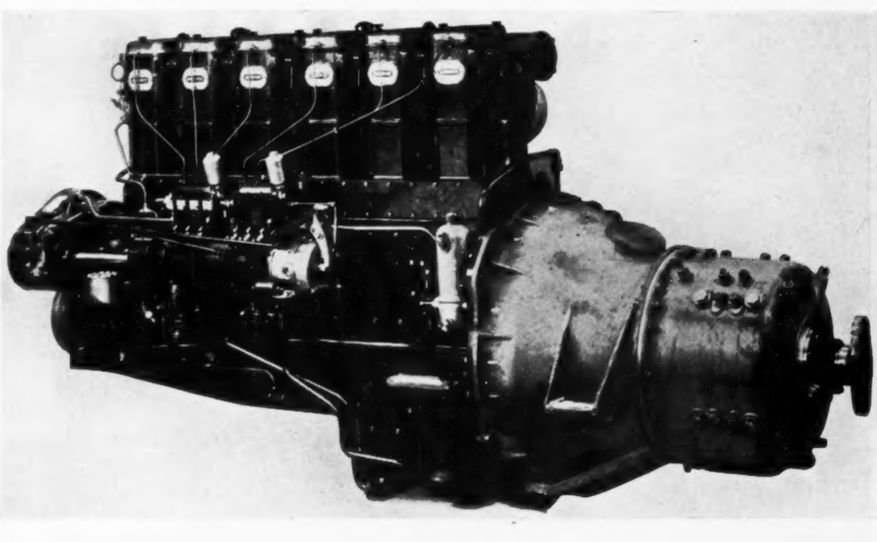
The power equipment comprises a Gardner 6L3 engine normally giving 153 b.h.p. at 1,200 r.p.m. but in this example derated to give a maximum of 141 b.h.p. at that speed from six 5¾-in. by 7½-in. cylinders. It is mounted on a subframe attached rigidly to the frame structure of the power bogie, but with a strip of balata between the two frames. Projecting through the floor of the driving compartment, the engine is covered by a steel bonnet with lift-off side doors, above which are four A.C.-Sphinx oil-bath air filters. A Spiral Tube radiator is carried on the front of the power bogie and is protected by a lift-up grille in the end panel; it has elements for water cooling and oil cooling, and the engine is fitted with a separate pump to maintain the oil circulation through the cooling system. The radiator fan is belt-driven from the engine shaft. C.A.V. 24-volt auxiliary electrical equipment is provided and includes a dynamo and starting motor on the engine. A cylindrical fuel tank of 40 gal. capacity is carried beneath the bonnet on the near side, and the filler and dipstick project through the bonnet top.

Transmission

Unit construction of the engine has been adopted and within the bell-housing is an 18-in. single-plate Borg & Beck clutch and behind it a Cotal four-speed electromagnetic epicyclic gearbox with a torque capacity of 125 metre-kg. or 900 lb.-ft. at 1,200 r.p.m. This is more than ample for any stress likely to be imposed by the engine, which has a torque of 669 lb.-ft. at 1,200 r.p.m. and a maximum of 704 lb.-ft. at 700 r.p.m. After the gearbox is a Layrub propeller shaft and, as a reverse is not incorporated in the gearbox, a spiral bevel and single-helical axle drive and reverse. Both axles of the power bogie are driven, the torque from the back axle being transmitted to the front through coupling rods, and as the wheels are inside the frames the rods are mounted on fly-cranks. With top engine revs. the gearbox gives track speeds of 9½, 13¼, 24½, and 40 m.p.h.; the driving axle ratio is 2·96 to 1, and the torque reaction from the axle gear casing is taken up by two substantial plate members supported on the main frame by means of robust rubber springs.

Mechanical Portion

The basis of the power bogie is two side plate frames very strongly braced by transverse and diagonal stays and headstocks, and this structure is carried on four 33-in. tyred disc wheels on axles spaced 8 ft. apart—the longest wheelbase so far used in a Walker power bogie of this type. The hemispherical pivot carrying the weight of the front portion of the car body is just above the propeller shaft. The outside axleboxes are equipped with Timken taper roller bearings, and are supported by overhung

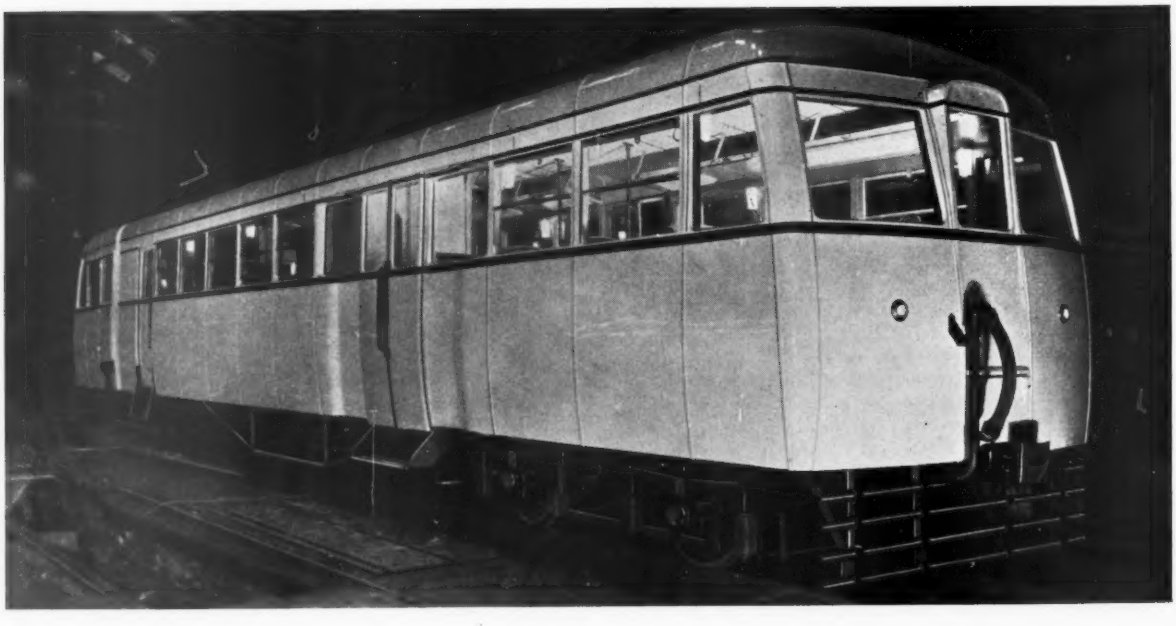


The power transmission unit of the Emu Bay car, comprising a 6L3 Gardner engine, Borg & Beck friction clutch, and Cotal four-speed electromagnetic gearbox. The top engine output at sea level is 153 b.h.p. when running at 1,200 r.p.m.

Above: Interior of front saloon and interior of driving compartment

Right: Interior of large saloon looking forward from the small compartment

Below: General view of the double-bogie car built by Walker Bros. (Wigan) Limited for the narrow-gauge lines of the Emu Bay Railway



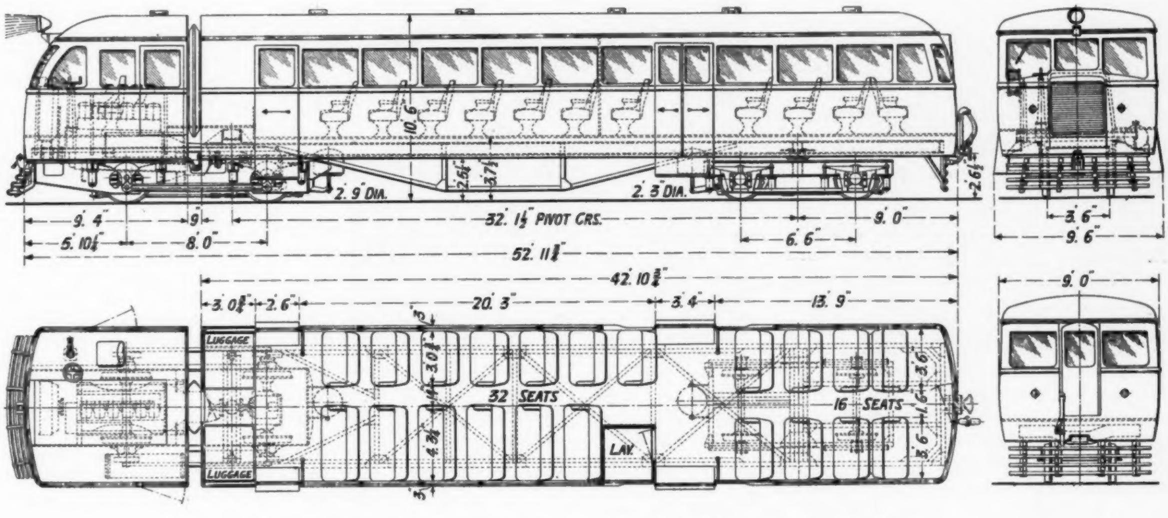


Diagram of 3 ft. 6 in.-gauge Walker railcar for the Emu Bay Railway

laminated springs of adequate flexibility. Made by Jonas Woodhead & Co. Ltd., each driving bogie spring has a span of 3 ft. 10½ in., and is arranged to be flat under load. The second plate is turned up past the eye at the end, so that if by any chance the solid eye should fail, it is retained in position and the hanger cannot become loose. The hangers are fitted with helical steel auxiliary springs.

The trailing bogie is of a light type built up on frames of steel channel, and has 27-in. wheels on axles supported by Timken taper roller bearings. In this case, too, the pivot is of the hemispherical pattern, and is supplemented by cast-steel side bearers and springs. Vacuum brakes operate single blocks with renewable shoes on all wheels of the car, and in addition the power bogie can be braked by hand. The rigging is compensated, and is independent on each bogie; a 15-in. cylinder is carried on the inner headstock of each bogie. Piping is fitted for the operation of vacuum automatic brakes on the trailers. The exhauster, carried on the power bogie and belt-driven from the front of the engine crankshaft, is of the two-cylinder reciprocating pattern with a capacity of 50 cu. ft. a minute, and was built by Walker Bros. (Wigan) Limited, under licence from the Vacuum Brake Co. Ltd. Gravity sanding is applied to the power bogie wheels and is operated by a pedal at the driving position. Central buffing and draw gear is fitted at the back of the car, but only a light emergency coupler and a cowcatcher are carried at the front end.

Car Body

The 42½-ft. underframe of riveted steel channels and sections carries a steel panelled body built by East Lancashire Coachbuilders Limited, of Blackburn, and painted outside in cream with green linings. Entrance and exit are accomplished through one double and one single sliding door on each side, and the panelling is set in slightly so that the doors do not project beyond the body width. The interior is arranged in two saloons, one—at the back—with two seats on each side of a central gangway, and the larger with 32 seats arranged three and two a side. All seats have Dunlopillo fillings and are covered with real hide. A lavatory is installed and at the forward end of the car there is room for a small amount of luggage. Straps for standing passengers are hung from the roof. Apart from the two rear seats, all the seats in the car face forward, and the Beclawat Typhoon Major half-drop windows are arranged to give a good view right round. Windows are fitted in the front bulkhead and coincide with windows in the back partition of the driving cab, so that a view is gained in a forward direction. Windows are also arranged round the back of the car, so that passengers in the four rear seats are in the equivalent of an observation car. Blinds are fitted to each window.

Electric lighting is incorporated, and in addition to a row of lights down the centre of the ceiling there is a row of vertical wall lights down each side panel. The lighting circuits, gearbox controls, windscreen wiper, horns, and the engine starter are fed from an Exide battery of 148 amp.-hr. capacity which is housed in a steel box behind the driving seat. Heating of the passenger saloons is accomplished by circulating the engine cooling water through copper pipes running along the floor close to the side panels, and is controlled by a valve in the driver's compartment.

Controls

In order to give the best possible visibility and ease of control to the driver, the floor at the sides of the engine room is dropped below the floor level of the vestibule leading from the car, and the front window lights are higher than those at the sides. In his seat at the right-hand side the driver has within immediate reach the throttle control handle with dead-man attachment; the gear change lever; the vacuum brake handle; an easily-operated clutch pedal; hand brake; engine starter button on the side of the bonnet; horn switch; light switch; screen wiper switch; and sanding pedal. Within clear view is a Teloc recording speedometer, and a small panel containing engine oil-pressure and oil-temperature gauges; the vacuum brake gauge; and an ammeter. The driving compartment has a swing door on each side with aluminium kicking plates just below door level.

ENGINE BEARINGS.—Progress is being made in the use of aluminium-base bearing metals for the crankshafts and crankpins of high-speed internal-combustion engines. Nickel and copper are among the alloying elements present in small quantities. It is claimed to have a lower coefficient of friction than lead-bronze and whitemetal, and to have a great fatigue strength. One such metal, patented by Rolls-Royce Limited and High Duty Alloys Limited, is now being made under licence by Wellworthy Piston Rings Limited.

DIESEL TRACTION IN DENMARK

Progress and practice on the State Railways during the past 15 years were described by the General Manager, Mr. P. Knutzen, in a paper presented to the Danish Institution of Engineers

THE Danish State Railways began railcar traction in 1925, and in the following four years 40 two-axle and three-axle petrol railcars with mechanical transmission were put into service. Some of these have since been sold to private railways, a few scrapped, and of the remaining 29 one is being converted to an emergency car for maintenance of the overhead wires in the Copenhagen electrified suburban area. In 1929-30 the State Railways bought 16 four-axle petrol-electric cars each with two engines of the automobile type; particularly for these heavy cars, weighing 45-46 tons gross, it has been found that this type of engine is not fit for arduous railway work, and they are being replaced by diesel engines. However, to avoid extensive rebuilding of the whole car it has been found necessary to use a light oil engine.

In 1927 experiments with diesel engines were begun, and the next five years may be regarded mainly as an experimental period. Every year a few cars or locomotives were bought to give the Danish industry an opportunity to reach a technically satisfactory type which could be produced in series. Railcars and locomotives were powered with relatively quick-running and slow-running engines respectively. A few of the locomotives have been scrapped, and a few of the railcars have at one time or another caught fire and been burned out. In three of the railcars the engines have been scrapped and replaced with newer types, and similar replacements are to be carried out in two more cars. Two-stroke and four-stroke engines have been tried, but only the four-stroke type has been found sufficiently reliable.

Modern Cars and Trains

Finally, what is known as the MO-type of double-bogie railcar was evolved. This class has two oil engines placed side by side and of 250 b.h.p. each, but the first ten cars had engines set to 225 b.h.p. Including nine cars under construction, the Danish State Railways have 59 railcars of this general type, together with five spare engine bogies and four spare traction motor bogies. Further, there are eight Lyntogs (Lightning trains), with two spare engine bogies and two spare traction motor bogies; the engines in these trains are of the same type as in the MO railcars, so that the State Railways have in hand about 160 of this diesel model.

The Lyntogs were something quite new in motive power for the Danish State Railways, and in the first four sets certain minor faults had to be rectified. These trains had a brake cylinder for each brake block, 32 in all for a three-car train, and after some trouble, particularly under snow conditions, the arrangement was altered to the usual, with one larger brake cylinder for each bogie. The brake drums could not stand the high temperature associated with high-speed applications, and they cracked and destroyed the friction linings of the drum blocks. Cast drums and thin welded drums with ribs were tried, but did not prove efficient, and now very thick cast drums are used, and are giving no trouble at the moment.

Snow Difficulties

There were no snow ploughs on the Lyntogs. It was thought that even if it should be necessary to stop running these trains a few days every winter this would be a small inconvenience compared with the great advantages on the remaining 360 or so days. However, some of the runs of the Lyntogs are so long that there may be local snow hindrances without any difficulties in the other parts of the country, and as the trains have proved so popular that the inconvenience of temporary withdrawal is greater than originally supposed, trials were made with small snow ploughs. These were difficult to arrange, as there are special limitations to the loading gauge for running on board the ferries, and the traction motors have small rail clearance. Further, placing a snow plough on the front bogie alone might give rise to an unduly high thrust on the bogie pivot. Two different constructions were tried, one with a plough attached to the front of the car underframe, and one with a plough on the bogie, but neither of these was satisfactory. A combination of the two forms is used at the moment, most of the snow being cut away by the plough attached to the car body.

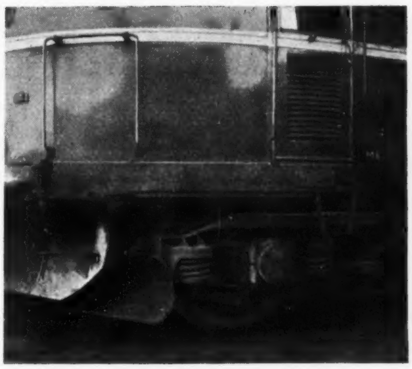
Traction Motor Troubles

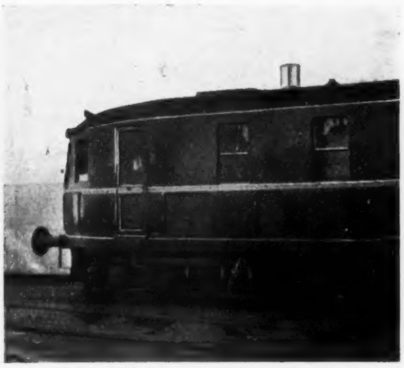
The electric traction motors have given some trouble under snow conditions, and it was to such a cause that the fire on a Lyntog in December, 1938, must be attributed. Design limitations prevented the adoption of enclosed self-ventilated motors, and in winter the train often ran through a fog of fine snow which was sucked in with the cooling air and melted in the heated motors. Short circuits ensued, and melted the soldered connections of the windings in the frame so that the copper winding strips were crushed and hurled up into the ventilation duct. The ventilation arrangements have been changed, and the air intake is led up in the space between the corridor connections; the motors now remain practically dry even after driving through snow. In certain vehicles the air intake under snow conditions is led through the luggage room and this causes a heavy draught, but if necessary one of the ordinary compartments can usually be reserved for the guard on the few snowy days.

The newest motors have been made without soldered connections and the older motors have been altered. Filter grilles are now fitted to the air intakes, the ventilation ducts have been lined with steel plates, and the woodwork behind the plates impregnated against fire. A further steel plate is placed between the floor and the traction motor bogie, and asbestos between this steel plate and the floor. The room above the engine bogie is fireproofed and has floor and walls of steel plate. Finally the high-tension cable conduits have been impregnated against fire.

Maintenance and Oil Consumption

The first batch of Lyntogs was fitted with rather stiff springs, as it was feared that there might be considerable side rolling movement when running fast. As such movements have not been experienced the springs have been made more resilient. All these alterations have been charged to the maintenance bill, and yet the maintenance expenses for the Lyntogs were only 45·4 øre per train-km. in 1938-39 and will be a good deal lower during the current year. A fair idea of the extent of general engine maintenance can be obtained from the consumption of lubricating oil. Per 1,000 gross *tonne*-km. this consumption in the MO cars has been 0·79, 0·70, 0·31, 0·34, 0·40,





Two views showing the front end of the Lyntog diesel-electric units of the Danish State Railways. The left-hand view shows the snow plough—mounted partly on the bogie and partly on the underframe—and the helical auxiliaries to the main bearing springs. The right hand view shows the details of the bogies as now running

0·48, and 0·31 kg. for the years 1932-33 to 1938-39 respectively. For the first half of the present financial year the figure is 0·24. For the Lyntogs which began running in 1935-36, the corresponding figures are 0·13, 0·30, 0·17, and 0·11 kg. per 1,000 gross *tonne*-km.

The Danish State Railways have no really high-speed oil engines in traffic, and no work is being done in the direction of raising the engine speed limit. But at the moment preliminary trials are being made with pressure-charging. Experience abroad shows that noise troubles can easily be avoided. A completely new vehicle type has now been ordered, consisting of two cars permanently close-coupled together, powered by two 8-cylinder pressure-charged diesel engines of 500 b.h.p. each, equipped with six traction motors, and having about 90 tons adhesion weight. This twin-car set will contain luggage room and 120 seats and will be able to pull up to six ordinary bogie carriages, thus forming a train with a capacity of up to 600 seats.

Large diesel locomotives thoroughly suited to Danish conditions have not yet been constructed. The relatively short distances and the comparatively few trains on the outlying lines do not present potentialities for the intensive or economic use which would justify the heavy first costs, and, further, it is difficult to arrange the electric transmission system so that the locomotive is suitable for fast as well as slow running.

Lyntog Services

Since the full Lyntog service was introduced in 1937 with fast railcar services in correspondence on the secondary lines, and in some places with connecting bus services, the whole country is practically covered by the Lyntog network. Even between Lolland-Falster and North Jutland there are two daily services in each direction. The ordinary trains have a seat occupation of about 30 per cent., but in 1938-39 the Lyntog had an average of 62 per cent. of the seats occupied for the whole length of their run. Normally the Great Belt is crossed daily by about 2,450 Lyntog sets. The daily mileage of a Lyntog set, including time off for periodical overhauls, is 650 km. (405 miles), and for a railcar about 325 km. (202 miles). The application of railcar and railcar-train traction has cost about 25 million kroner.

Railcar Life

The life of diesel rolling stock is actually a maintenance problem. Every part is replaced when worn out, but it is practically impossible to wear out the car itself, so that the life is really unlimited. The problem therefore is not the wear and tear of the car and the engines, but rather obsolescence, which comes when a more economical form of propulsion has to be found, or when it is considered necessary to provide still better accommodation for the passenger. The Lyntogs run 240,000 km. (149,000 miles) a year each, so that by May next the first four Lyntogs will have covered 1,200,000 km. (746,000 miles) each, and in many respects they are today even better than they were when new.

LETTER TO THE EDITOR

The Function of Railcars

London, S.E.3
March 9, 1940

To the Editor of the Diesel Traction Supplement

Sir,—Your remarks on the function of railcars on p. 13 of the *Diesel Railway Traction Supplement* dated February 16 were most opportune, and I sincerely hope they will be taken to heart when the time comes for the reconstruction of passenger train services. In spite of many examples from Continental railway practice, the only cases here where railcars have been put to their proper use are on the Great Western Railway (the Birmingham—Cardiff and, to a lesser degree, the Bristol—Westbury—Weymouth services), and in the north-eastern counties for such connectional services as Hull—Selby—Pontefract, which did not justify a steam train. The L.M.S. three-car diesel unit, after some very bashful appearances between Oxford and Cambridge on a schedule which made it of little value to the public, was actually used to supplant slow and semi-fast steam trains between St. Pancras, Leicester, and Nottingham.

Yet, even if we admit that the high-speed steam train may be the most satisfactory way of providing acceleration on routes where a good passenger business is already assured, there are, on the L.M.S. system alone, many areas which would profit greatly from a fast railcar service. Cross-country routes, such as Birmingham to Peterborough or Crewe to Nottingham, are obvious examples, while in the Furness district, railcars based on Barrow could improve the terribly bad communication for businessmen along the coast from Barrow to Workington, and could give fast services to connect with main-line expresses at Carnforth or Lancaster.

Your reference to the "present shocking level" of punctuality is also fully justified. During the first eight months of 1939 the average late arrival at London termini of fast trains by which the writer travelled was 9·8 min Provincial arrivals were better, averaging 6·1 min. late, but a combined average of lateness (on a total of about 300 journeys) of 7·3 min., as against an average of 0·74 min. for 54 express journeys in France during the spring of 1939, is very depressing.

R. E. CHARLEWOOD

NOTES AND NEWS

Oxygen Starting.—Failing to get the diesel engine of a power excavator to start, a workman at Rosyth borrowed a cylinder of oxygen for injection into the cylinders. On turning the engine an explosion occurred, and one man was killed.

Ruston-Paxman Combination.—Ruston & Hornsby Limited, of Lincoln, has acquired the whole of the share capital of Davey, Paxman & Co. (Colchester) Ltd. The Paxman business will continue as heretofore under the managing directorship of Mr. E. P. Paxman.

New Zealand Railcars.—According to Mr. D. G. Sullivan, Minister of Railways, the New Zealand Government Railways are to build depots at Oamaru, Invercargill, Ranfurly and Lumsden in South Island in readiness for the ten 275 b.h.p. diesel-mechanical railcars now on order.

Exhaust Conditioning.—An exhaust filter and purifier for diesel locomotives is the subject of a recent patent (No. 515,347) taken out by C. Donington, E. H. Fox, and Ruston & Hornsby Limited, the principal feature of which is the use of sawdust or slag wool, kept moist automatically by the passage of the gases.

New Horizontal Engine.—The Hercules Engine Corporation has developed its six-cylinder HXB, HXC, and HXD ranges of four-stroke vertical engines into single-bank horizontal models with cylinders 5 in. by 6 in., 5¼ in. by 6 in., and 5½ in. by 6 in., and outputs of 140, 155, and 170 b.h.p. at 1,800 r.p.m.

N.S.W. Diesel Cars.—During the fiscal year 1938-39 the five 720 b.h.p. diesel-hydraulic power vans of the New South Wales Government Railways made an aggregate mileage of 273,258, but the fifth power van was not put into traffic until well on into the year. The five power cars and 12 special trailers covered an aggregate of 1,059,144 vehicle-miles during the year.

Queensland Railcar Statistics.—During the fiscal year 1938-39 the railcars of the Queensland Government Railways covered 2,393,080 miles and 43,422,249 ton-miles. At the end of the year the stock comprised 71 railcars and 129 trailers; 102 of the trailers were for passengers, 11 for goods, 14 for cream traffic, and 2 convertible from one form of traffic to another. A policy is being pursued of converting petrol cars to diesel, principally in the 50 and 100 b.h.p. sizes. Owing to the widespread railcar services it has been felt desirable to inaugurate a regular system of training for railcar drivers and mechanics; therefore an instruction car has been built and is sent to various centres in charge of an instructor.

American News.—On December 1 further diesel-operated New York—Florida services were begun, this time by the Atlantic Coast and Florida East Coast Railroads, with four seven-car trains hauled by Electro-Motive 2,000 b.h.p. locomotives. The Northern Pacific is purchasing three 1,000 b.h.p. and four 660 b.h.p. diesel switchers as part of its 1940 programme. The morning Twin Zephyr has been accelerated again, to 6 hr. for the 431 miles between Chicago and St. Paul, an overall average of 71·9 m.p.h.; the train has been slightly re-routed through the outskirts of La Crosse. The first Alco main-line diesel locomotive has just been built; it is a double-engined 2,000 b.h.p. unit for the C.R.I. & P. The last-named railroad now has in traffic two double-bogie 40-ton Davenport-Besler diesel-electric switching locomotives, each equipped with two 180 b.h.p. Caterpillar engines and four Westinghouse traction motors. The tractive effort up to 2½ m.p.h. is 24,800 lb., and curves of 75 ft. radius can be negotiated. The Missouri Pacific budget for 1940 includes $580,000 for the purchase of 11 diesel-electric switching locomotives. The Wabash has ordered one Alco and one Electro-Motive 660 b.h.p. diesel-electric switchers, and the Oliver Iron Mining Company ten Baldwin and seven Alco diesel-electric locomotives. The nine Rocket trains of the Chicago, Rock Island & Pacific Railroad covered 1,629,132 miles during 1939, but as the Rocky Mountain Rockets were not placed in traffic until November 12, the average yearly mileage of the first seven trains was 217,500 each; the total number of passengers carried during the year was 516,691. Diesel locomotives completed in the U.S.A. during 1939 totalled 251 for home service and three for export according to the U.S. Bureau of Commerce statistics, compared with 111 and one in 1938.

Trade Publications

Filters.—The design and maintenance of the A.C. oil filter and oil-bath air filter are described in the A.C. Service Book issued by the A.C.-Sphinx Sparking Plug Co. Ltd., of Dunstable. The air filter of this make has been applied to many Gardner-engined railcars described over the last few years in the pages of this Supplement.

Horizontal Engines.—The large horizontal Crossley-Premier engines in powers up to 1,000 b.h.p. in the single-bank form and up to 3,000 b.h.p. as *vis-à-vis* models, are illustrated and described in two publications, Nos. 1880 and 1850 respectively, just sent to us by Crossley-Premier Engines Limited, of Sandiacre. Both normal and pressure-charged forms are available, the latter having electrically or mechanically driven blowers. Prior to the war this company completed a higher speed horizontal engine suitable for heavy shunting locomotives.

English Electric Engines.—The successful four-stroke engines built for rail traction work by the English Electric Co. Ltd. are illustrated and their dimensions and outputs listed in a six-page brochure, No. W61. The H type, for railcar installations, is made in six-cylinder and eight-cylinder models giving 220 and 294 b.h.p. at 1,500 r.p.m.; the K type is used for locomotives, such as the L.M.S.R. shunters, but is applicable also to stationary purposes, and in this form or for traction is used by all four of the British group railways and by the L.P.T.B. Pressure-charged models with considerably higher outputs are available.

Fowler-Sanders Engines.—Under the title of *Achievement*, John Fowler & Co. (Leeds) Ltd. has published a 24-page brochure recording the wide variety of applications of the Fowler-Sanders two-way swirl oil engine. Portable generating sets, automatic pumping sets, road rollers, fire pumps, concrete mixers, and screening and breaker plants all come within the scope of one or other of the Fowler-Sanders models, but with natural regret we observe that only a single page is given to diesel locomotives, one of the most prominent of the Fowler activities. We hope that despite war conditions another publication dealing solely with the firm's railway work will not be long in reaching our desk.

Kadenacy Engines.—The Kadenacy principles applied to two-stroke engines (see issue of this Supplement for December 22, 1939) have been given so much discussion, some of it quite acrimonious, in the technical press, that we have awaited with some trepidation the time when next we would dare to deal with this important engine subject. Fortunately our excuse is a brochure issued from the Slough laboratories of the Armstrong Whitworth Securities Co. Ltd. itself. In the hands of experts the subject is dealt with as the inventor would wish, and we are left in the happy position of toastmaster, and in introducing this 22-page publication —The Kadenacy System for Two-Stroke Cycle Engines—need say only that it covers the principles completely yet lucidly, and that the descriptive matter is supported by excellent illustrations.

Diesel Railway Traction

A Hundred Per Cent. Availability

A SERVICE availability of 100 per cent. over a period of 365 consecutive days has been achieved by one of the twin-unit 3,600 b.h.p. diesel-electric locomotives of the Baltimore & Ohio Railroad. Scheduled to haul the Capitol Limited daily over the 772 miles between Washington and Chicago, locomotive No. 56 did not miss a day between February 25, 1939, and the same date in the present year, covering in that period, a mileage of 282,000 at an end-to-end average speed of 56 m.p.h. inclusive of ten intermediate stops per trip. The regular make-up of the train comprises anything from 11 to 15 cars. At each end of the trip arrival is in the morning and departure the same afternoon, and the longest stationary period for servicing during the year was 6½ hr., but doubtless maintenance work was carried out *en route*, as is done in most American long-distance diesel trains. As we recorded in the issue of this Supplement for June 9, 1939, the official view of the Baltimore & Ohio is that it would be impossible to haul the Capitol Limited on its present fast schedule by any steam locomotive on the line, but that diesel traction can, and does, do it with time in hand. These locomotives have the 2(A1A-A1A) wheel arrangement and weigh about 285 short tons; they are said to be capable of three-figure speeds when hauling trains of 650 to 670 short tons.

Firedamp as a Fuel

THE need for one or more thoroughly practicable fuels as alternatives to petrol and diesel oil certainly does not diminish as the war is prolonged and it is not unlikely that the need will spread to non-belligerent countries. Although producer gas has made progress, and quite a few years' experience is available, no alternative fuel has greater *prima facie* attractions than methane, not even the fuel of the motorist who, finding himself seven miles from home with an empty tank and no ration coupons, is reported in the daily press to have poured a bottle of whisky into the tank and safely reached his destination. Methane (CH_4), which is the principal constituent of sewer and mine gases, differs from other alternative fuels in that its use in the engine appears to present no great difficulty; the trouble is all in the collection and storage. The use of liquefied methane seems to bristle with difficulties, and we believe that in the Italian railcar which is running on methane experimentally, the fuel is carried in cylinders as a compressed gas, probably at a pressure of 75 to 90 lb. per sq. in. According to experience in Middlesex, where methane is now being collected from sewage and stored in bottles, this fuel can be sold at a price equivalent to 10d. to 12d. a gallon of petrol. It has been thought that one possible source of large methane supplies would be the shale oil industry, but in the workings of Scottish Oils Limited, to quote one example, very little firedamp is encountered; however, in the oil drillings found in various parts of England a considerable quantity of natural gas is available, although it is not likely to be set free simply for use as engine fuel. Once in the engine, methane gives a good account of itself for it has a high anti-knock value and does not produce a greatly diminished power compared with petrol or oil. But probably it will need appreciable purification, particularly to get rid of hydrogen sulphide and any other sulphur compounds which have a deleterious effect on ferrous metals.

Oil-Engine Exports

ANOTHER important step towards the eventual almost complete rationalisation of the oil engine industry appears to have been taken by the precipitate formation of a war export group of the Internal Combustion Engine Manufacturers' Association, on the lines suggested in the Government White Paper dealing with the functions of the Export Council created in March. That, in the midst of a war caused to a large extent by the struggle to export enough to maintain a "favourable" trade balance, the Government should be seeking to intensify the export fight may seem little short of criminal. In making returns of material used and material required, and agreeing to detailed investigation of their figures should any Material Controller desire it, the members of the I.C. engine war export group may find that they have supplied data useful in having rationalisation forced on them in post-war years, if not before, at the instance of the institutions which now control the issue of the nation's financial credit. Such figures have time and time again in the last 20 years been used to assist in restricting the activities of this firm or that, in an endeavour to cut down the abundance of goods to fit the extraordinarily meagre amount of purchasing power or credit available to individuals and industries. The sole object of any association is the benefit of the individuals comprising it, who, by working together, can achieve results desired by all but which would be impossible if the members operated singly. Although much sympathy must be extended to manufacturers struggling in the meshes of the system by which industry in general is financed, it is not quite clear just how they are going to benefit by allowing their association to play them straight into the hands of those who have every intention of controlling them at no distant date by the arbitrary restriction of financial credit. How little understood is the real control of credit and all it implies may be gauged by the printing in the Red Book issued by the association of statements of four bank chairmen, apparently as part justification for the formation of the war export group. One need only remark that within two years of the arbitrary restriction of financial credit after the last war, something like seven-eighths of the enterprises floated in 1919 and the first half of 1920, along with many old-established businesses, had come under the complete control of the joint stock banks. Through their control of credit facilities the banks hold the volume of production in their hands at all times—export trade or no export trade—and no committee or group or course of action which fails to take account of this, and rectify it, will do anything but still further centralise the control of industry and eliminate the private business.

A DOZEN NEW RAILCARS FOR THE B.A.P. RAILWAY

European diesel-mechanical design brought up-to-date for broad-gauge passenger and parcels traffic

IN view of the success obtained with the six diesel railcars placed in service at the end of 1937 (see issue of this Supplement for February 18, 1938), three of which have mechanical transmission and the other three hydraulic transmission, the Buenos Ayres & Pacific Railway has recently purchased a further 12 Ganz units, eight of which are passenger cars and the remainder are for parcels and light goods traffic only. As a direct result of actual service observations on the operation of the first six cars, the company has found it desirable to make various modifications and improvements in design, material or manufacture of the present 12 cars, for a clear demonstration had been given by the working of the first six cars that European manufacturers did not fully appreciate the many difficulties encountered in Argentina due to dust, volcanic ash and weeds; nor were they conversant with the precautions necessary to prevent such matter from entering the engine-room and body of the coach generally.

Passenger and Parcels Duties

Two types of railcars have just been purchased, to the requirements and specification of Mr. R. E. Kimberley, the railway company's Chief Mechanical Engineer. The general overall proportions of the two varieties are the same, and the design of the parcels vehicles is such that they can be converted into passenger vehicles if necessary without major structural modification. The diesel engine, transmission and control gear are identical in both types of cars, and all replaceable parts in the running gear are interchangeable. In the passenger cars a total of 60 fixed seats together with lavatory and luggage or parcels space has been provided. In the case of the parcels cars the floor space is intended to accommodate 10 tons, but in addition a fully-equipped postal compartment has been provided; there is also a lavatory compartment for the use of the train crew and postal employees. As an experiment, one of the parcels cars has been fitted with six folding seats in the passageway between the postal and parcels compartments, the intention being that passengers may be carried in case of emergency.

The contract concluded with Ganz & Co. Ltd., of Budapest, called for delivery of the 12 cars before the end of October, 1939, but owing to the outbreak of hostilities and difficulties of transportation, delivery has been delayed. Alternative shipping arrangements have now been made by which all 12 cars will be in the Argentine Republic in time for the introduction of the next winter timetable (middle of 1940) of the B.A.P. Railway. Under present arrangements it is proposed that the 12 new cars should operate from the important town of Villa Mercedes, which is also an important junction on the railway system, and arrangements are already well advanced for the servicing and maintenance of the cars at this centre.

Framing

The underframes for both types of car are of the pattern supplied for the previous six cars, but modified to suit the proportions of the new design. The frame is of light-weight construction and built up of rolled steel members welded electrically, and so designed as to form a composite welded structure with the body framing. The side pillars are of pressed steel U form, and the cant rail and roof members are of light-weight rolled steel sections welded electrically and forming part of the main structure. Automatic couplers have not been fitted on these railcars, but the design of the underframe is such as to allow for the incorporation of these fittings at a later date. Instead of cowcatchers as on the six cars built in 1937, the inclined front of the cars has been extended down to rail level and is suitably stiffened internally. The body framing is of the same grade of material as the underframe. All partitions throughout the body structure are of steel framed design welded to and forming part of the whole, the intention being thereby to stiffen the structure and thus ensure a longer life. Particular attention has been paid to the reinforcing of the central entrance vestibule in order to avoid twisting of the bodywork.

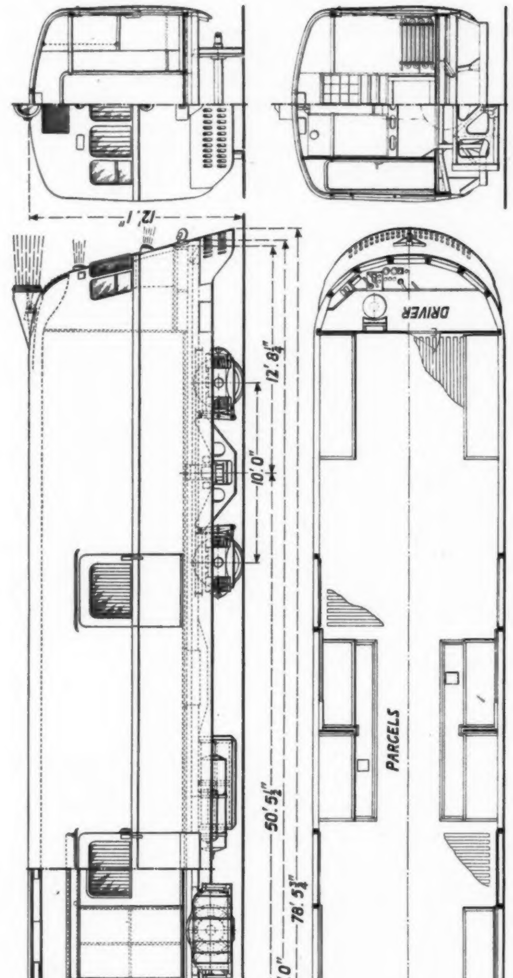
All the panelling has been electrically welded to the body framing. The whole of the external panelling has been sprayed on the inside with asbestos composition supplied by J. W. Roberts & Co. Ltd., of Leeds, in order not only to give adequate insulation from the intense heat experienced in Argentina during the summer months, but also to prevent drumming of the plates.

Interior Arrangements

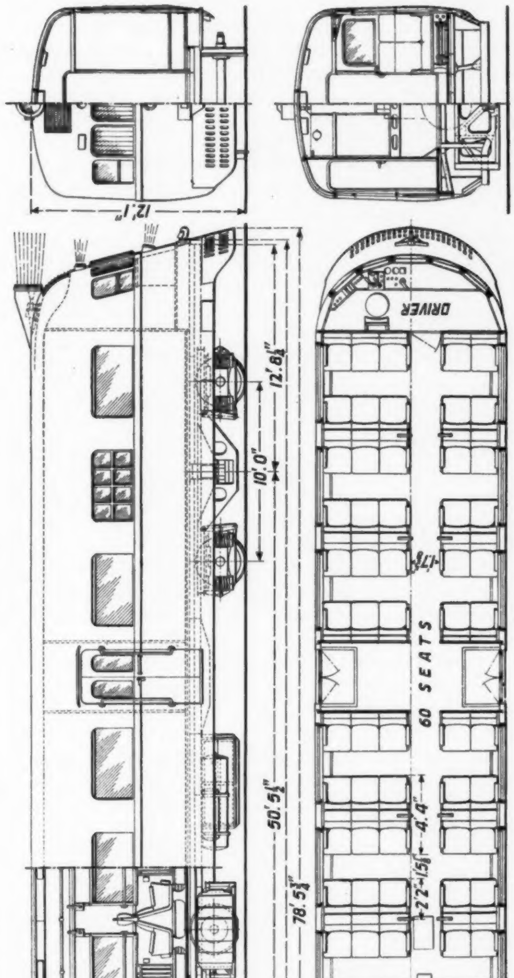
The interior panelling of the passenger saloons above the waistline is of 4-mm. walnut plywood with a highly-polished finish; that below the waistline is of aluminium sheathing except below the windows, where an alloy casting has been introduced to form the bearing or housing for the window lifting mechanism, and in this way the mechanism can easily be taken out for adjustment or repair. The roof panelling is also of 4-mm. plywood. Frameless bevelled mirrors of oval shape are fitted on the saloon side of the entrance vestibule and also on the partition next the W.C. and luggage compartments. Windows of the full-drop type have been fitted and are therefore not wholly interchangeable with those on the previous cars. Louvre blinds are fitted on the outside of the windows and have aluminium frames and hard wood renewable slats. The rubber seal on the lower frame is dovetailed instead of being secured by screws as done on the previous cars. The windows in the driver's cabin are made of specially toughened safety glass and the two side windows can be lowered by means of suitable mechanism. The three centre windows are provided with protection grids on the outside on the same lines as the previous cars.

The supports or pedestals of the seats have been redesigned to give better facilities for cleaning the cars. The spaces between the seat backs have been kept as open as possible for the accommodation of luggage, and the covering of the seat backs is of aluminium sheeting, which cannot be damaged by the movement of passengers' luggage; there is space below the seats for small hand luggage. The intention has been to give a seat of the maximum comfort and utility, which will nevertheless conform to the dimensions laid down by the Argentine Government.

The lavatory compartments of the passenger railcars are panelled with aluminium suitably painted in a washable cream colour. The lavatory hopper is to the Argentine broad-gauge standard and the seat is spring-controlled to come back automatically to the upright position. A water seal has been fitted in the discharge pipe and a pedal-



General arrangement and layout of broad-gauge parcels and light goods railcar



General arrangement of the latest diesel-mechanical passenger railcar, Buenos Ayres & Pacific Railway

operated positive flushing device has been provided. In addition, by means of a hand pressure pump the guard can flush the hopper from time to time. A water tap has also been provided in the compartment for the convenience of the cleaning staff. The window is of opaque glass and can be lowered for about 10 in.

Lighting and Communications

The lighting equipment, with the exception of the batteries, is similar in every way to that fitted on the previous cars. The accumulators are of the nickel-cadmium type. The battery boxes are arranged with frontal flaps and 9 in. head-room has been allowed for ease in taking density readings without removing the batteries from the car. All the electrical equipment was supplied by J. Stone & Co. Ltd. In addition to a high-power headlight, a shunting headlight for use in stations and yards is located in the centre front panel of the car below window level. Desilux compressed air horns, of the largest size suitable for railcars, are used; one horn has been fitted at each driver's cabin and is operated by a push button.

Air intakes communicating with longitudinal roof ducts have been located over the driver's cabins at each end, and the fresh air, uncontaminated with dust, is distributed through adjacent grilles in the passenger saloon. This system of natural air ventilation has already been successfully employed by Ganz on other railcars in Argentina.

Each driver's cabin has an electric bell, by which the guard can communicate with the driver. Bell-pushes for the use of the guard are fitted to the entrance vestibule of the passenger cars and on each side of the interior of the parcels cars. Bell-pushes are also located over the windows on which the line-clear apparatus is located and above the doors of the luggage compartment. An electric bell of a tone completely different from that in the driver's cabin is located in the parcels compartment of the passenger cars and in the interior of the parcels cars, and is connected with bell-pushes conveniently located on the driver's control panels in order that the driver may call the guard.

In the parcels cars the postal compartment is completely independent from the rest of the vehicle, as all such compartments in Argentina are under the direct control of the State postal authorities. A letter-box is provided on the side of this compartment for the use of the public at wayside stations. When the letter-box is not in use, the opening can be plugged with a metal plate bearing a caption in Spanish, as an indication to the public that it is not in use.

Bogies and Brake Gear

The diesel engine and transmission are mounted on an all-welded steel bogie with a wheelbase of 12 ft. 11½ in. through the medium of double rubber pads. The Kimberley type of body suspension has again been incorporated and is interchangeable with that fitted to the previous six cars. The greasing nipples have been grouped together in an accessible place on the bogie to facilitate lubrication and they have also been provided with a protective cover. The design of the trailing bogies closely follows that of the motor bogie; construction is of all-welded steel and here again the Kimberley body suspension system is used. This particular type of suspension was evolved in an endeavour to get a vehicle which would ride a good deal more comfortably and smoothly than the normal railway coach, and it does away with the bogie centre for purposes of weight transfer, distributing the weight of the body directly to the side members of the bogie. The universal joint necessary to provide for the relative movements of the body and bogie was obtained by forming a spherical seating on the bogie side member through which passes a suspension link having at its lower extremity a ball joint making connection with the bracket member on the underframe. At the upper end of the link the load is taken through a helical spring which is provided with a spherical seating washer. The traction forces are transmitted from the bogie to the underframe and body by means of a cross-member and a pin sliding in a slot. In addition to being slanted in a transverse direction, the swing links are set at a slope in the longitudinal direction, the direction of inclination being opposite on each side.

As certain difficulties have been experienced in service in Argentina with the driving axles of railcars, special attention was paid to the quality of material used for the wheels and axles of these 12 new railcars, and Taylor Bros. & Co. Ltd. was entrusted with the manufacture of the wheels and axles for both engine and carrying bogies. Knorr compressed air brakes have been fitted, but the capacity of the compressors is 25 per cent. greater than on the previous cars. To meet this requirement a two-stage compressor has been supplied in place of the single-stage unit previously fitted. An oil separator has been introduced in the delivery pipe line from the compressor to the reservoir in order to prevent the oil from finding its way from the cylinder into the pipe system. Hand-brake equipment has been fitted in each driving position and is arranged to apply the blocks on the adjacent bogie only. Apart from the increase in the ratio desirable, due to the increased weight of the vehicle, the brake leverage has been increased compared with that found in the previous six cars. Emergency brake valves have been fitted in convenient positions in the luggage compartment. An electrical cut-out switch forms part of the emergency valve assembly to avoid dust interfering with the switch, and the whole has been enclosed in a neat casing with only the handle of the emergency brake valve protruding.

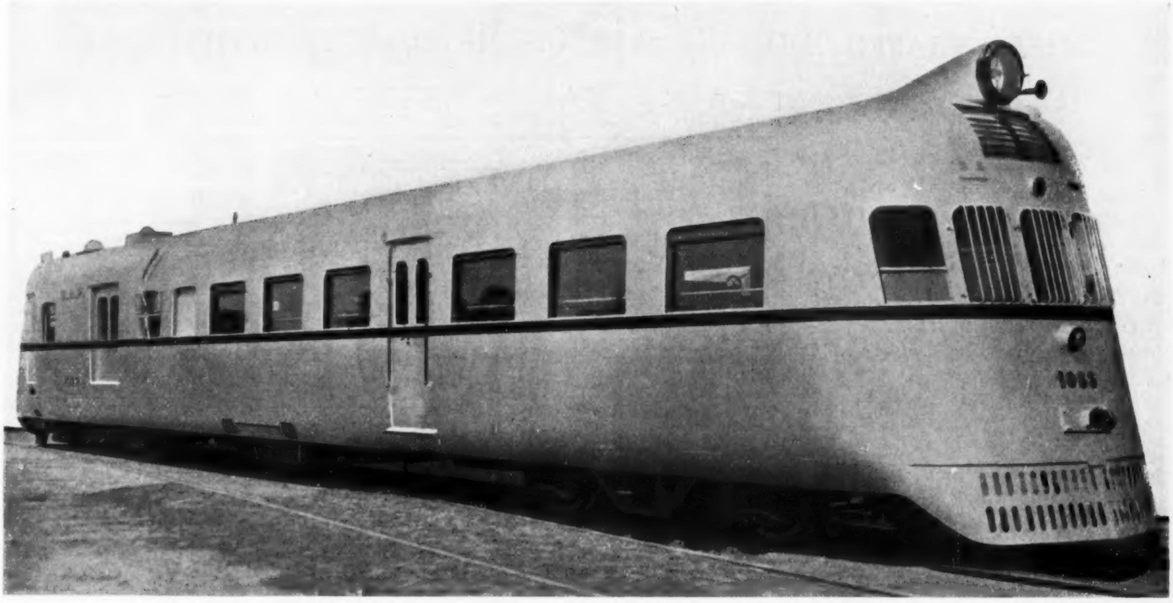
Engine and Transmission

The power unit comprises a six-cylinder Ganz VI JaR 170/240-type engine. The design now includes aluminium pistons and the latest form of Ganz-Jendrassik precombustion chamber. This engine has a maximum possible test-bed output of 310 b.h.p. at 1,450 r.p.m., but normally is set to give a maximum of about 240 b.h.p. at 1,250 r.p.m. Dual starting motors are fitted and are arranged for either independent or simultaneous synchronised working. The detail arrangement is such that the starting motors always take up exactly the same position after removal for examination or repairs. The air-intake filter is of a type specially designed to cope with Argentine conditions.

The Ganz five-speed transmission is of the maker's present standard type, but compared with three of the six original cars on the B.A.P. the main clutch and reverse gear are now located at the rear end of the engine bogie instead of being grouped adjacent to the engine flywheel. This permits of much greater accessibility and gets over the difficulty of misalignment when a very short cardan shaft is employed. Some trouble due to this cause was experienced in the operation of the first six cars. All cardan shafts were specifically ordered with all-metal universal joints instead of the fabric discs previously employed by Ganz. The top gear step gives a maximum track speed of 97 km.p.h. with new tyres and an engine speed of 1,250 r.p.m., and the normal operating maximum is limited to 90 km.p.h.

The radiator for the engine cooling water, the dynamo, and the air compressor are mounted on small sub-frames carried beneath the car underframe. The drive for these is taken from the reverse gearbox by a cardan shaft running at engine speed and is distributed through the medium

(*Continued on page* 53)



One of the latest single-engined double-bogie Ganz passenger railcars

Interior of the main saloon of the passenger railcars with double-end drive

VIEWS OF THE LATEST RAILCARS OF THE BUENOS AYRES & PACIFIC RAILWAY

MIXED-TRAFFIC DIESELS FOR U.S.-MEXICAN FRONTIER LINE

Subsidiary line of the Mexican National Railways now operates all regular traffic by standard-gauge diesel-electric locomotives

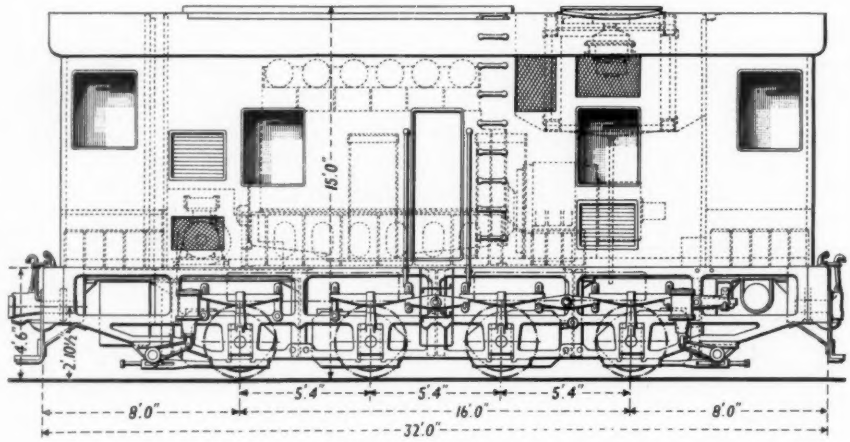


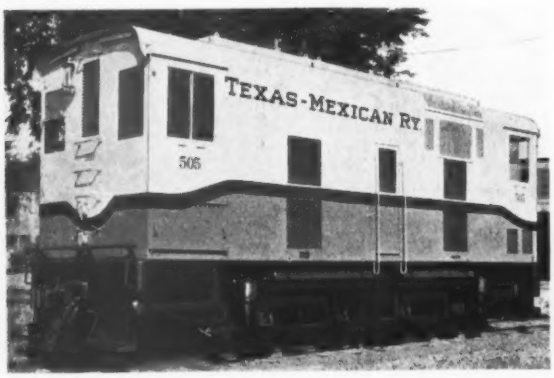
Diagram of 58-ton diesel locomotive, Texas-Mexican Railway

THE main line of the Texas-Mexican Railway extends for 163 miles from Laredo to Corpus Christi, both in the State of Texas. The freight and passenger services (usually mixed) and the shunting at the stations are now worked entirely by seven diesel-electric locomotives supplied by the Baldwin Locomotive Works, and built by that firm and its subsidiary the Whitcomb Locomotive Company, of Rochelle, Illinois. Normal trains consist of a passenger car, a baggage car, and five or six freight vehicles, but to deal with the considerably greater tonnages prevalent at peak periods, multiple-unit control is incorporated in the locomotive design. Light rails severely restricted the axle load, but as the line has no sharp curves it was found possible to use a four-axle rigid-wheelbase locomotive which could be run safely up to 40 m.p.h. These units are working to the same schedule and hauling the same loads as the previous steam engines, but the fuel cost is only about one-eighth of the old figure. Hauling 860 long tons over a distance of 240 miles the fuel consumption is about 260 U.S. gal.

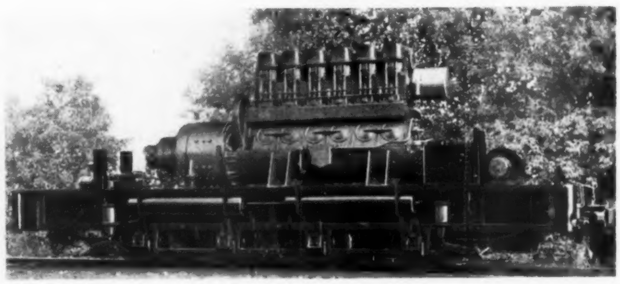
A six-cylinder Baldwin-De La Vergne oil engine forms the power-producing unit and is set to give 660 b.h.p. at 600 r.p.m. in cylinders 12½ in. by 15½ in. Water cooling is carried out in vertical sectional radiators supported by the cab structure. Mounted on a common bedplate with this engine is a Westinghouse main generator which for its general applications has a continuous rating of 1,200 amp. 500 volts at 850 r.p.m. The overhung auxiliary generator has a continuous rating of 340 amp. 125 volts at 600 r.p.m. Electro-pneumatic control is incorporated and gives series and parallel motor combinations without field shunting. The four traction motors operate through 16 : 79 gears and are force-ventilated by a single 9-h.p. blower running at 1,800 r.p.m. A 56-cell Exide-Ironclad battery is fitted to provide the engine starting and auxiliary circuit currents.

Side frames of the cast steel bar type form the main structure of the locomotive. They are braced by five cast steel cross ties secured by fitted bolts; the three centre ties take the weight of the engine-generator combination. The 7-in. axles are carried in plain boxes suited to journals 5½ in. by 10 in. and are supported by overhung laminated springs. The springs of the first and second axles are side-equalised only, whereas those of the third and fourth axles are both side- and cross-equalised, this arrangement giving three-point suspension. The cab is of all-steel welded construction and has a driving compartment at each end.

Westinghouse straight and automatic air brakes are used, and four vertical 10-in. cylinders apply one flanged block on each wheel. Air is furnished by a motor-driven reciprocating compressor having a capacity of 80 cu. ft. of free air a minute at 925 r.p.m. In each driving cab is a hand brake wheel to apply blocks on two wheels to hold the locomotive at rest. Air sanders, a Pneuphonic horn, and electric lighting are included.



Two views of the 660 b.h.p. diesel-electric locomotive and its engine and transmission equipment



METHANE AS AN ENGINE FUEL

Sewer gas or firedamp is an excellent fuel technically, but the problems of its collection and storage have not been fully solved on a commercial scale

The widespread proposals to use methane (CH_4) as an alternative fuel for internal-combustion engines directs attention to two papers read recently in which reference was made to the potentiality of this gas as a fuel for transport engines. Brief abstracts of these papers are given below.

DR. C. M. WALTER, in the course of his paper "Alternative Motor Fuels," read before the Royal Society of Arts on February 28, said that the most important characteristics of fuels in their application to internal-combustion engines were the heat of combustion per unit volume of charge; the composition of the products of combustion; the specific heats of the products of combustion; the volumetric efficiency; and the change in the number of molecules after combustion. A great deal of interest had been shown in the use of methane as an alternative fuel for motor vehicles, as it had been a very satisfactory fuel for internal-combustion engines by reason of the high compression ratios which could be used owing to the low velocity of combustion. It was also exceedingly clean in use, very little carbonaceous deposit being formed in the engine.

The sources from which methane could be obtained were:

(*a*) Sludge gas from sewage.
(*b*) Production from town gas or coke-oven gas by catalytic methods.
(*c*) Blow-holes in coal mines.
(*d*) Natural sources associated with the production of shale oil.

The approximate composition of sludge gas was methane 70 per cent. and carbon dioxide 30 per cent. It also contained small quantities of H_2S, which had to be removed, otherwise this and other sulphur compounds would seriously affect bottles and other equipment in storage systems. The chief advantage of methane over other gaseous fuels from the point of view of storage was its high thermal concentration owing to the high calorific value, and to the fact that the capacity of a storage cylinder, in petrol equivalent, was increased in direct proportion to the calorific value. A further advantage was obtained because methane at high pressure did not obey Boyle's Law. At a pressure of 3,000 lb. per sq. in. the product PV was decreased by 23 per cent., representing an increase in the volume of free gas which could be stored, as compared with town gas at the same pressure. Taking an ordinary standard vehicle cylinder of 1·76 cu. ft. water capacity and using a town gas of 475 B.T.U. per cu. ft., its capacity at 3,000 lb. per sq. in. in petrol equivalent was 1·1 gal., whereas with methane the corresponding figure was 2·85 gal.

* * * *

Dr. J. Ivon Graham in his paper "Firedamp—Its Occurrence in Mines and Possible Utilisation," read before the South Wales Institute of Engineers on October 26, 1939, said that methane was the main constituent of the gases evolved from coal, although nitrogen and carbon dioxide might exist in appreciable quantities. The mining engineer's purpose in the past had been to dilute and render innocuous the gas formed underground, but the loss to the nation of such a vast quantity of valuable fuel probably amounted to the equivalent of more than 1,000,000 tons of coal a year. Furthermore, methane as a fuel was provided ready in a form which could be utilised with a high degree of efficiency.

A simple calculation brought home the vast wastage of material from even a single pit. One-half per cent. of CH_4 in 250,000 cu. ft. per min. of upcast air gave 1,250 cu. ft. per min., or 1·8 million cu. ft. per day. This was equivalent in calorific value to 54 tons of coal of 14,000 B.T.U. a day. Compared with petrol, 1·8 million cu. ft. a day was equivalent to 12,587 gal. a day. Methane had a calorific value about twice that of town gas, and consequently the radius of action of any vehicle using compressed methane was approximately double that of one using coal gas. Experimental work by Mr. H. R. Ricardo had shown that methane was a fuel *par excellence* for internal-combustion engines, a H.U. compression ratio of 16 to 1 being possible with this gas in an engine with spark ignition.

The collection of methane from underground workings other than where blowers were in existence was not an easy matter, and much painstaking research would be necessary to ascertain the economic and technical possibilities for doing this. The alternatives for collection on the surface were:

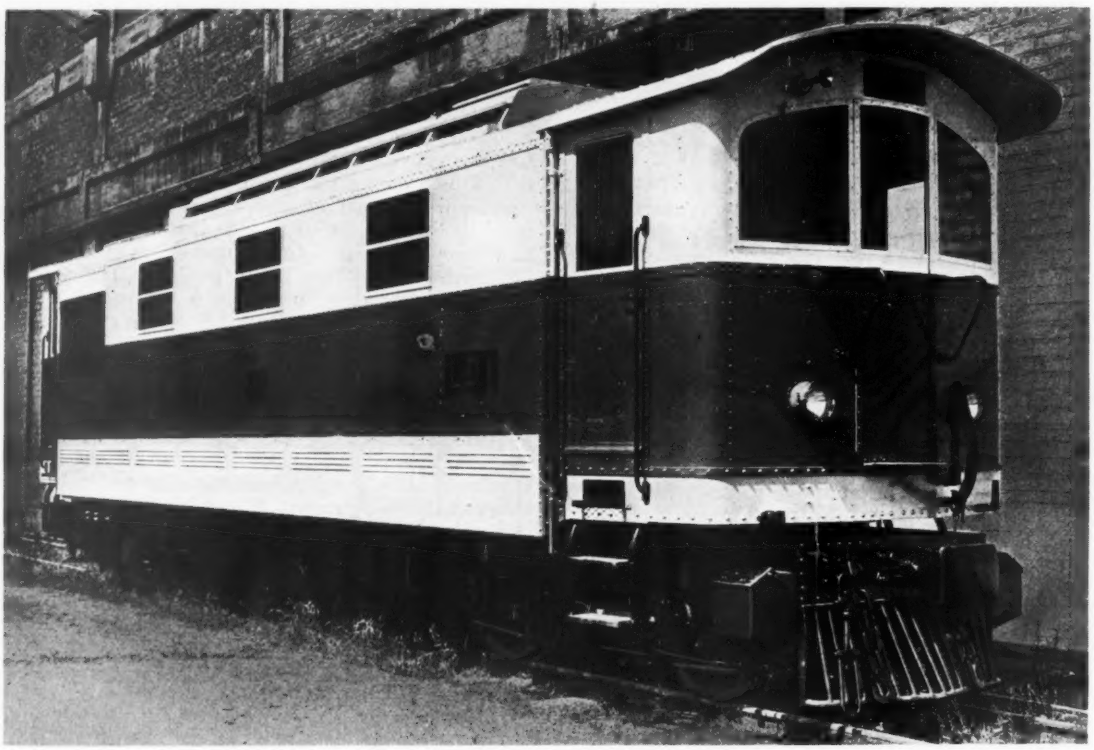
(*a*) Storage in gasholders of large capacity under approximately atmospheric pressure.
(*b*) Storage under pressure at about 200 atmospheres in cylinders, or in metal or reinforced rubber containers filled with charcoal, at about 6 atmospheres pressure.
(*c*) Liquefaction.

If the subsequent use of the gas could be carried out at atmospheric pressure, the first system of storage was all that was necessary. Compression in cylinders was an obvious means for transport. Owing to the readiness with which methane could be adsorbed by material such as charcoal, the quantity of firedamp which could be stored in any space at a definite volume might be greatly increased by filling the storage vessel with highly adsorbent material. Greatest advantage in this respect would be obtained at pressures slightly lower than or slightly above atmospheric. With a container filled with an activated charcoal, at a temperature of 30° C., approximately seven times the quantity of methane could be held at a pressure of 5 atmospheres as could be held in the container at the same pressure if no charcoal was present, and at lower temperatures the ratio would be much greater; the advantage would not be so marked if pressures much in excess of 5 atmospheres were used.

Liquefaction was being carefully studied. It would appear that if 2,000 gal. a day or more were liquefied, the cost of liquefaction would be under 2d. a gal. The pressure would not be so great as for compressed gas, 60 atmospheres being sufficient for liquefaction. Liquid methane had a specific gravity of 0·45, or approximately half that of commercial petrol, but the boiling point was −160° C. and the critical temperature −90° C. Obviously, either vacuum or extremely well lagged tanks would be necessary for the storage of the liquid, and for the required evaporation some means of controllable heat transmission into the liquefied gas would be required.

DIESEL LOCOMOTIVES FOR HEAVY GRADES

Metre-gauge design for Madagascar has a top service speed of 37 m.p.h., 35½-in. wheels, multiple-unit control, and gives a starting tractive effort of 26,500 lb.



61-ton diesel locomotive with continuous rated tractive effort of 17,600 lb. at 9·6 m.p.h. which has six nose-suspended traction motors grouped in parallel

IN 1937 the French Ministry for the Colonies placed an order with the Soc. Als-Thom for three diesel-electric locomotives for operation over the newly-constructed Fianarantsoa—Manakara line, and in 1938 increased the order to five, as a decision had been made to use diesel traction on the Tamatave—Tananarive section. Both lines have long grades, sharp curves and rise to an altitude of over 3,500 ft. The first line has 1 in 34-35 grades combined with 80-metre (263-ft.) curves, and 1 in 28½ grades on the straight; the length of the line is 103 miles and the maximum height 3,600 ft. The Tananarive line is 230 miles long and has 1 in 40 grades and 50-metre (164-ft.) curves; the line rises to a height of 4,900 ft. above sea level and on the branch from Tananarive to Antsirabé to 5,740 ft. The axle load is limited to 11 metric tons, and the locomotives are expected to haul 185-ton trains up the 1 in 28½ grades, and up to 270 tons in the reverse direction, when the grade is 1 in 40.

The unusual triple-bogie Bo-Bo-Bo wheel arrangement has been adopted. The centre bogie is allowed considerable lateral play, and is fitted at each end with controlling links coupling it with the adjacent bogies. Buffing and drawgear is fitted on the extremities of the outer bogies, but is not transmitted direct through all bogies, going along the main underframe between the pivots of the outer bogies. Flange lubricators are fitted, and in conjunction with the short rigid wheelbase of 6 ft. 6 in. allow of a reasonable tyre and flange life despite the sharp curves. The centre bogie pivot is midway along the wheelbase, but in the outer bogies is set inwards to the extent of 2½ in.; the pivots are pitched at 12 ft. 4 in. from each other and the total wheelbase is 31 ft. 7 in.

A girder-frame cab structure extending the full length of the locomotive rests upon each bogie by means of hemispherical pivots and two flexible side supports. It was built in four sections, bolted together to facilitate unloading and transport in Madagascar. The centre part forms the engine and equipment room and has a large removable roof section; at each end is a driving cabin.

Power is furnished by a Sulzer 6LDA25 engine pressure-charged by an exhaust-gas turbo blower to give a maximum of 735 b.h.p. at 830 r.p.m., but actually under the conditions prevailing in Madagascar a limit of 625 b.h.p. at 790 r.p.m. has been set. The circulating water is cooled in two radiator banks mounted vertically on the cab sides, and through which air is drawn by two motor-driven fans. As usual in Sulzer practice the engine and main generator are mounted on a single welded steel underbed. The Als-Thom-Royer electric control system, which operates in conjunction with Sulzer's rheostat regulation, gives automatic regulation of the output. It is characterised by a main generator with three windings, and by a separate exciter which feeds a special winding in the traction motors to give additional excitation at starting and to give an automatic progressive increase in the amount of field shunting as the locomotive speed rises.

SPANISH RAILCAR PROGRESS

THE use of railcars on the Spanish railways, which appeared to be following the great advance made in other European countries, suffered a serious setback during the civil war. Apart from isolated instances, the first railcar services date back to 1926, but it was not until 1932 that the principal companies extended the use of these vehicles on their systems. By July, 1936, at the time of the outbreak of the civil war, the Northern Company had 19 two-axle petrol cars with Ford engines, and 18 diesel-engined cars of different types, to which were added later six Arpad 275 b.h.p. bogie cars delivered by Ganz to the Republican government during the war. At the same date the Madrid, Zaragoza & Alicante Company had 14 diesel railcars and three special trailers. The majority of these cars fell into the hands of the Republicans at the outset of the civil war, especially on the M.Z.A. system, which was principally in Republican territory. However, 13 of the Northern Company's Ford cars and four of the M.Z.A. diesel cars remained in the hands of the Nationalists. The four diesel cars were of the two-axle Renault 150 b.h.p. type with mechanical transmission, and these small vehicles gave good service during the war, running constantly between Valladolid and Zaragoza, where, indeed, they are still running. Subsequently, the railcars which had been used by the Republicans were found to have suffered severely from the stress of war and from accident and neglect.

Railcar Services

With the termination of the civil war (the occupation of Madrid took place on April 10, 1939) work was immediately begun on the repair of the cars which were found disabled, and many were soon in service again. The M.Z.A. now runs a daily service between Calatayud and Caspe, through Zaragoza, 208 km. (129 miles) each way, with two Renault cars of 150 b.h.p., at an average speed of 59·5 km.p.h. (37 m.p.h.), and a similar service, with a Burmeister & Wain-engined bogie car with electrical transmission between Barcelona and Reus, 105 km. (65 miles) each way. Another successful service is that between Madrid and Cuenca, 202 km. (125·5 miles) each way; this run is performed by two Renault 265 b.h.p. cars with mechanical transmission, although at the beginning, in 1935, Maybach-engined cars of 410 b.h.p. were used. The most ambitious of these post-war diesel services is the daily trip between Madrid and Barcelona. This run, also on the M.Z.A. system, is performed with three of that company's four Maybach 410 b.h.p. bogie cars with electric transmission. The distance is 685 km. (425·6 miles) and the booked speed is 58·5 km.p.h. (36·3 m.p.h.) including all stops except that of 40 min. for lunch at Zaragoza. The company reports that some of these Maybach cars have run as much as 125,000 km. (77,671 miles) without overhaul.

Railcar Costs

The companies have furnished details of the working costs of their railcar services, compared with the running expenses of the passenger trains they have replaced. The Northern Railway figures for 18 small petrol cars running before the civil war over an aggregate of 832,233 km. (517,133 miles) show that the actual operating expenses averaged 0·38 pesetas per railcar-km., or, at an exchange rate of 40 pesetas to the £, 3·7d. per railcar-mile. Even with amortisation added at the very generous rate of 0·75 pesetas per km., the gross cost amounted to only 1·13 pesetas per railcar-km., or 10·9d. per railcar-mile. This represents an economy of 2·50 to 3 pesetas per train-km. (24d. to 29d. per train-mile). The same company quotes the two Ganz 120 b.h.p. four-wheel cars, over an aggregate distance of 116,426 km. (72,500 miles), as averaging a cost of 0·36 pesetas per railcar-km. which is slightly less than the working cost of the much smaller Ford-engined petrol vehicles, although, as the capital cost of the diesel cars was greater, the amortisation charges are correspondingly higher.

The M.Z.A. has also kept account of railcar working costs, especially those of the 265 b.h.p. Renault cars running between Madrid and Cuenca. During five months of 1935-36, 85,000 railcar-km. were run (52,816 railcar-miles), replacing 74,000 steam train km. The comparative working costs were:

	Pesetas	£
74,000 train-km. steam traction	260,761	6,519
85,000 railcar-km. diesel traction ...	64,285	1,607
Saving in running expenses	196,476	4,912

These cars cost 581,757 pesetas each (£14,544), but in spite of this high first cost the original outlay could be repaid in a relatively short period with the economy shown in working, and at the same time an improved service is given to the public.

During the civil war and since its termination, the four Renault 150 b.h.p. four-wheel railcars of the M.Z.A. running between Valladolid and Zaragoza, have averaged 253 km. (157 miles) a day. Working costs including amortisation have been given as 0·78 pesetas per railcar-km. (7·5d. per railcar-mile). Traffic earnings of these 42-seater railcars have averaged 2·12 pesetas per km., giving a surplus of 1·34 pesetas per railcar-km., which, for the 75,000 km. (46,603 miles) run by each car annually, means a profit of about 100,000 pesetas (£2,500). Steam train operation over the line was costing at least 3 pesetas per train-km., and a deficit has therefore been converted into a profit, while at the same time affording an improved public service.

Finance and Future Plans

Under the system of control exercised by the State over railway finance in Spain, and in view of the difficulties in obtaining fresh capital for the acquisition of new equipment, a Ministerial Order dated March 15, 1935, was issued, authorising the companies to purchase railcars and to charge the cost and interest, spread over a period, to working expenses. The Order was annulled by the Republican Government but was re-established on July 29, 1937. In order to finance such purchases a "National Railcar Company" (*Compañia Nacional de Automotores*) was formed in Madrid with a capital of 10 million pesetas, and financed by the Northern and M.Z.A. Railways and six of the leading banks. Under this arrangement Spanish manufacturers are now executing orders for 12 double-bogie cars with two 145 b.h.p. Fiat engines, and eight bogie cars with 265 b.h.p. Renault engines and mechanical transmission. Half of these cars are for the Northern Company and half for the M.Z.A.

The Northern Railway has in hand a project for the construction of 11 diesel-electric trains with which it is proposed to establish fast long-distance services between Madrid and the northern ports of Vigo and Corunna, Gijon and Santander. With rapid diesel-electric trains it is believed that the present steam train timings to the northern provinces could be reduced by one third. This plan was initiated some years ago (see issue of this Supplement dated November 29, 1935), but it had to be suspended owing to the civil war. Both the Northern and M.Z.A. are experimenting with diesel shunters, which in time it is hoped will supersede the present system of shunting with train engines.

WARTIME DIESEL TRAFFIC IN DENMARK

An account of the extraordinary war and weather difficulties which have beset the express diesel services on the Danish State Railways during the past seven months

ON September 6 the Copenhagen—Esbjerg—Copenhagen Lyntog, Englaenderen, was discontinued in consequence of the stopping of the Esbjerg—Harwich steamship service. On September 7 the Frederikshavn—Flensburg(Germany)—Frederikshavn Nordpilen fast service was withdrawn. This service was worked by ordinary diesel motor-coaches (class MP) and trailers, and not by Lyntog stock, although the State Railways' posters showing the Nordpilen have depicted Lyntog sets. On September 12 the timings of certain ferry journeys on the Great Belt were eased in order to save fuel, but the change was made only in cases where the delay thus caused could be caught up by shortening station stops; details were not published.

Emergency Timetable

A temporary winter timetable was introduced on September 20. As all preparations for a peacetime winter timetable, including printing, had been concluded before the outbreak of war, there was no time to recast entirely the timetable from the outset. Instead, the necessary reduction of services was made by cancelling a large number of trains and making actual changes only where this was absolutely necessary. The effect on the Lyntog runs was that the Englaenderen (Copenhagen—Esbjerg—Copenhagen) remains withdrawn; the Kronjyden (Copenhagen—Frederikshavn—Copenhagen) runs only as far as Aalborg; the Vesterhavet (Copenhagen—Ringkøbing—Copenhagen) stops short at Esbjerg; the Midtjyden (Copenhagen—Struer—Copenhagen) runs only to Skive; and the Østjyden (Copenhagen—Struer—Copenhagen), and Nordjyden (Copenhagen—Aalborg—Copenhagen) continue unchanged. The Vesterhavet on its up journey to Copenhagen had conditional stops introduced at Sorø and Ringsted without increase in journey time; this resulted in a timing of 7½ min. for the 9 miles between Sorø and Ringsted, but timekeeping was not expected. A reduction of the speed limit of the Lyntog from 120 to 100 km.p.h. (75 to 62 m.p.h.) was foreshadowed at the beginning of the war, but this reduction has not materialised so far. A number of diesel services all over the country were either withdrawn or replaced by steam trains, but on the other hand certain petrol-powered railcars on branch lines were displaced by diesel stock.

Floating Mines in Great Belt

From December 10 the evening Lyntog services in both directions have no longer been transferred across the Great Belt. The official reasons given for this step are not quite clear, but it seems likely that the appearance on several occasions of floating mines on the ferry route have made the railway administration disinclined to risk losing a ferry plus two Lyntog sets at the same time by carrying on sailings in darkness, when a proper lookout is practically impossible. Arrangements were made for trains of the same type to be used on both sides of the Great Belt, so that passengers could use seats of the same numbers in both trains. The timings remain unchanged, but passengers are requested to transfer as quickly as possible between train and ferry and *vice-versa* in order to minimise delay. The Lyntog services thus affected are three up trains (Østjyden, Kronjyden, Vesterhavet) and two down trains (Midtjyden and Nordjyden); in order to balance the workings an empty train must therefore be transferred by ferry from Nyborg to Korsør once a day. It was also necessary to change certain trains from three-coach to four-coach sets and *vice-versa* in order to obtain identical trains for each service on both sides of the Great Belt.

New Winter Timetable

On January 15, 1940, an entirely recast timetable came into force. The total economies as compared with peace timetables are about the same as for the temporary timetable introduced on September 20, but connections are much improved in a number of cases, and, curiously enough, several of the Lyntog services are actually speeded up quite noticeably, owing to the fact that better paths for them could be found because of the reduction in frequency of other services on the lines concerned. The most important alteration is that the up Østjyden now runs behind the Kronjyden, thus giving a much needed connection from North Jutland to South Jutland and Fyn. The arrangements introduced on December 20 remain in force, but provision is now made for the extra time required at the ferry terminals. The Østjyden has fixed stops at Sorø and Ringsted, and the temporary apparent 72-m.p.h. timing disappears, and is replaced by a 54-m.p.h. start-to-stop schedule (10 min. for 9 miles). The Kronjyden and Vesterhavet up trains, which connect with the same ferry, are now worked every day of the week in multiple-unit as one train from Korsør to Copenhagen, with stops at Slagelse and Roskilde; hitherto this was only the case on Sunday evenings. Before the war the same arrangement applied to the Englaenderen and Ostjyden trains from Korsør to Copenhagen on Sunday evening.

Lyntog Service Suspension

From January 20 all Lyntog services were temporarily suspended as a result of greatly increasing difficulties with ice on the Great Belt crossing. It was not found possible to continue the workings between Nyborg and the Jutland terminals of the trains, as certain essential periodical overhauls to the sets can be carried out only at the Copenhagen end; therefore passengers have been taken by the remaining steam expresses on the Great Belt and Kalundborg—Aarhus routes. From February 1 until March 5 no transfer of railway vehicles across the Great Belt was possible, and from February 2 until February 26 the crossing was entirely closed.

On March 17 the normal Lyntog traffic (according to the timetable of January 15) was resumed, opportunity having in the meantime been taken to give all eight sets a thorough overhaul and clean up, but the very next day, March 18, a severe snowstorm blowing from the south-east and several floating mines observed near the crossing route caused complete suspension of all traffic across the Great Belt during the hours of darkness, and the evening Lyntog in both directions were suspended. The storm continued throughout March 19, and the ice-pressure in Nyborg fiord became so great that all four diesel ferry vessels were stuck fast in the morning. The three westbound vessels were released by icebreakers

Map of Danish railway system showing location of the Great Belt Ferry route in relation to the long-distance services

during the course of the day, but the eastbound ferry, the *Nyborg*, had to spend the night in the ice, finally reaching Korsør after a journey lasting 24 hr. The morning Lyntog from Jutland were not dispatched, and the morning Lyntog from Copenhagen had to return from Korsør with those passengers who did not elect to go *via* Kalundborg—Aarhus instead. Evening Lyntog in both directions were suspended.

The following day all services were carried through with more or less delay, but in Jutland a heavy silver thaw damaged a large number of telegraph lines, which in many cases fell across the railway and caused much delay to the Lyntog and other traffic. On March 21 a strong northbound current in the Great Belt brought large ice floes from the Baltic, and, in spite of assistance from three icebreakers, traffic on the Great Belt was once more entirely suspended, after the motor ferryship m.v. Korsør had been forced aground on a shoal off Korsør together with the assisting icebreaker ; the newest and most powerful ferry, the *Storebaelt*, had to return to Korsør with 1,200 passengers after four hours' vain attempt to force the ice. The evening Lyntog in both directions were withheld on Zealand, but carried through between Nyborg and Jutland.

BELGIAN PRODUCER-GAS CARS.—Of the 50 diesel railcars of Brossel manufacture which the Belgian National Railways ordered last year (see issue of this Supplement for September 1, 1939), 25 are now to be equipped with producer-gas plant. The cars already delivered or almost completed will have detail modifications made as opportunity offers, in order that they may be fitted with producer-gas plant if the liquid fuel situation was to become worse.

SWEDISH CARS.—The Nohab bogie luggage railcars operated by a number of Swedish lines, and having two 240 b.h.p. Hesselman engines running at 1,200 r.p.m., are limited to a top speed of about 43 m.p.h. when running on the narrow gauges and 50 m.p.h. on the standard gauge. Power is transmitted to the axles of each bogie by means of Lysholm-Smith hydraulic transmission, the pump wheels of which are fitted with adjustable vanes to give fine regulation. For the sake of simplicity the positions for the torque converter operation are limited to three, the first for running light, the second for starting and running at speeds up to about 33 m.p.h., and the third for speeds over 33 m.p.h. The 800-mm. ($31\frac{1}{2}$-in.) wheels are spread over a bogie wheelbase of 8 ft. 6 in., and the bogie pivots are 21 ft. 8 in. apart.

Western Australian Railcars

Special trailers have been constructed at the Perth workshops

SHORTLY after the Western Australian Government Railways put into traffic the six diesel-electric cars with Armstrong-Saurer power equipment (see issues of this Supplement for April 16, 1937, and September 2, 1938), it became obvious that the additional comfort and speed provided by these cars was so attractive to the public that the use of trailers had become necessary. Special trailers had not been built as part of the original contract, and a number of old saloon-type coaches were therefore converted for temporary use as trailers, and have continued in service up to the present time. It was always realised that these existing coaches would not be satisfactory as permanent units, and designs were prepared for six new vehicles to be built at the railway workshops.

The first of these new trailers has just been set to work. It is of all-steel construction and seats 20 passengers in the smoking saloon and 16 in the non-smoking section. There is a large compartment for parcels and light luggage and two lavatories are provided. In exterior appearance the trailers conform to the lines of the railcars themselves and the seating accommodation is also similar. Other features are wide windows, giving a good view all round, and folding steps of the type described in detail in the issue of this Supplement for April 14, 1939. The underframes are of the lattice-girder type and have been built up throughout by electric welding. The body framework, too, is electrically-welded throughout and similar construction has been adopted for the bogie frames. Roller-bearings are being used for the axleboxes. The tare weight is about 13 tons.

New Railcars for the B.A.P.

(*continued from page* 46)

of a small gearbox located on the first sub-frame. In order to obviate the difficulties which have already been experienced due to the entry of dust and volcanic ash into the air compressors the suction pipe for the compressors has been connected to a clean air supply and an adequate but easily cleaned filter also forms part of the equipment. The capacity of the fuel tank is 600 litres. As considerable inconvenience and delay have been experienced due to breakages of the flexible fuel pipe from the tank to the filter on previous cars, special attention was devoted to this point in the new vehicles.

Electro-pneumatic control of the engine and transmission is provided in both the driver's cabins. The electro-pneumatic valves in the present cars are not carried on the bogie but are installed in a special casing located in the passageway adjacent to the driver's cabin. A low-water indicator has been introduced into the cooling water system and is so arranged as to cut off the engine in the case of the water level falling below a predetermined line. This device was installed by the B.A.P. on the first six cars after they had been in operation for some time. In the first six cars use was made of the metalwork in the frame for the return circuit, but this was modified before the cars were actually placed in service. In the present 12 cars all the electrical equipment and installations have been entirely insulated from the body of the vehicle. A Hasler speedometer is fitted, in addition to the standard Ganz electrical speedometer.

NOTES AND NEWS

Powder Starting.—The A.B. Bolinder-Munktel, of Eskilstuna, Sweden, has patented a device for starting oil engines by means of a powder cartridge inserted in a sleeve leading into the combustion chamber.

Warming-Up Unit.—A portable unit for maintaining engine water temperatures for up to ten light internal-combustion-engined vehicles is now being made by the Equipment & Engineering Co. Ltd., of London, W.C.2.

Railcar Dispensary.—One of the railcars of the Italian State Railways has been fitted up as a dispensary and will travel about the provinces of Rome, Littoria, Frosinone, Viterbo, Rieti, and Terni, calling periodically at numerous towns and villages.

Monarch Ventilators.—The Monarch Controller Co. Ltd. asks us to state that the Walker railcar for the Emu Bay Railway, described in the March 15 issue of this Supplement, is equipped with Monarch ventilators for both the passenger saloon and the driving compartment.

Small American Diesels.—The G.E.C. has recently been building some four-wheel 20-ton 150 b.h.p. diesel-electric locomotives for sugar plantation railways, and the associated Canadian G.E.C. some 38-ton double-bogie diesel-electric locomotives with two motors, and the two pairs of wheels in each bogie connected by coupling rods.

South African Railcar.—A small bogie railcar, 32 ft. long and 7 ft. 4 in. wide, has been built in the Durban shops of the South African Railways, and is now working over the 2-ft. gauge Upington-Kakamas branch. It is powered by two Oldsmobile petrol engines of the type which can give 95 b.h.p. when running at 3,400 r.p.m. Seating accommodation for 21 Europeans and 7 non-Europeans is provided, and there is baggage room amounting to 36 sq. ft. The tare weight is 10·4 tons and the maximum permissible speed 30 m.p.h.

Ivory Coast Railcars.—Two French-built bogie railcars with luxurious accommodation are now at work on the metre-gauge Ivory Coast Railway. Each car is equipped with one of the latest CLM-Junkers two-stroke opposed-piston engines developing a maximum of 275 b.h.p. at 1,500 r.p.m. and drives the wheels through a Minerva four-speed presynchronising gearbox. The cars have six compartments, two sleeping saloons, a buffet-bar, lavatory, and postal compartment; air-conditioning is a feature. The body length is 55 ft., the tare weight about 23 tons, and the top speed 53 m.p.h.

Canadian Diesel Train.—The Temiskaming & Northern Ontario Railway has put into traffic a triple-car diesel-electric train rebuilt from an old Brill petrol-electric car and two storage battery railcars. Power is now furnished by a 250 b.h.p. Cummins oil engine mounted in the centre vehicle. The train can be driven from either end; its overall length is 187 ft., the weight without pay load 102½ tons, and the seating capacity 96. A large amount of baggage, parcel and mail space is provided, aggregating 71 ft. in length with full car width. Two trailers composed of ordinary stock have been hauled in times of heavy traffic.

Diesel Locomotive and Railcar Batteries.—In a paper on storage batteries presented to the Institution of Electrical Engineers by Mr. C. E. McKinnon, of the Chloride Electrical Storage Co. Ltd., it is stated that a typical British specification in connection with batteries for shunting locomotives with six-cylinder 350 b.h.p. engines requires a break-away current of 630 amp. falling in 2 sec. to 250 amp. at firing speed, which may persist for 30 sec. The battery must start the engine after the locomotive has been standing for two days in an air temperature of 0° C.; peak current and time may then be somewhat exceeded, and voltage must not fall below 48 on starting peak with battery half charged, nor below 35 volts when fully discharged.

Indo-Chinese Railcars.—The railcars of the Yunnan Railway have become more and more popular in the last two years. The frequency of the local trains has been doubled by the use of railcars, and three further cars with special trailers have recently been put into traffic in order to give a still further increase in the interurban service between Hanoi and Haiphong. For the long-distance service to Yunnanfu, the original Michelin with a seating capacity of only 15 has now been replaced by a new Michelin having 43 seats and with a special light trailer for baggage and parcels. During the year 1938 the Yunnan railcars covered an aggregate distance of 378,222 km., and the Michelins on the long-distance service 76,431 km.

Diesel Inspection Car.—A new type of four-wheel inspection car with four seats is now being produced by F. C. Hibberd & Co. Ltd., and is powered by a Victor Cub horizontal oil engine of the *vis-à-vis* pattern. This engine develops 13 b.h.p. at 1,600 r.p.m. and is governed to a top speed of 2,700 r.p.m. A four-speed Victor gearbox driving through a Hibberd Planet reverse box with chain-drive to the axles gives speeds of 4¾, 9, 13½ and 20 m.p.h. when the engine is running at 1,600 r.p.m. A Planet exhaust spark arrester is fitted. The car is 9 ft. 6 in. long, has 20-in. wheels spread over a base of 4 ft., and runs on 2-ft. gauge tracks. All the body panelling is of aluminium. A 10-seater car of the same general type but with a length of 13 ft. and a Victor Cub Senior oil engine of slightly greater power is now in production for operation in dangerous areas.

American News.—On February 25 diesel-electric locomotive No. 56 of the Baltimore & Ohio Railroad completed 365 consecutive daily trips hauling the Capitol Limited over the 772 miles between Washington and Chicago. The B. & O. believes this to be a world record for continuous service. The total mileage involved was 282,000, covered at an average schedule speed of over 56 m.p.h., including 10 stops per trip. The Chicago, Rock Island & Pacific has been authorised to spend $1,528,000 on diesel-electric locomotives and streamlined passenger stock. The Atchison, Topeka & Santa Fe Railroad has another four 2,000 b.h.p. express diesel locomotives from the Electro-Motive Corporation. Orders for 14 diesel-electric locomotives of 600 b.h.p. have been placed by the Delaware, Lackawanna & Western Railroad; eleven are to be built by the Electro-Motive Corporation and three by Alco. The Chicago & North Western reports that its new diesel 400 service has carried 51 per cent. more passengers during its first four months in service between Chicago and the Twin Cities than did its steam prototype in the corresponding period last year. The actual figures are (from October 1, 1939 to January 31, 1940) 73,234 against 48,663; and for the month of January 1940, 20,058 passengers compared with 12,895 last year. Three 600 b.h.p. diesel-electric locomotives are to be built by the Electro-Motive Corporation and one by Alco for the Lehigh Valley Railroad.

Diesel Railway Traction

Shunting in the Sudan

THE application of diesel locomotives to heavy and continuous yard shunting on the Sudan Railways has been attended with a considerable degree of success. Over a period of three years two 45-ton diesel-electric shunters at Port Sudan have shown working costs, including maintenance, only 45 to 50 per cent. those of corresponding steam power. On the other hand the capital costs of diesel-electric locomotives of this type were so high that owing to the consequent enormous interest and depreciation charges—comprising half the gross operating cost—the all-in working cost is still, if anything, slightly in favour of steam locomotives. With any fall in the price of diesel motive power compared with steam, a corresponding financial saving in gross working costs will then complement the proved advantages of the diesel as a traffic unit. In large yards where a fleet of shunting locomotives is operated in continuous work, three diesels may replace four steam engines, or seven may replace ten or thereabouts, but at Port Sudan, where the conditions are more nearly ideal for diesel operation than at any other yard on the system of the Sudan Railways, there is no opportunity for saving in locomotive numbers. At the other yards, for every night shunting shift there are two or three day shifts, owing to the incidence of train movements and shunting demands, so that the conditions are less favourable than at Port Sudan. The diesels appear to have given a performance which in normal times would warrant an extension, and it is not impossible that in future years the shunting at Port Sudan will be carried out entirely by diesel power, and displaced steam locomotives transferred to the other yards, such as Atbara and Khartoum.

Railcar Operating Experience

ALTHOUGH a good deal is heard from time to time about the poor service given by new diesel railcars of one make or another, it is often difficult to ascertain whether the troubles are any more or any less than can be expected with a new type of motive power operated by a staff with little or no experience in its design, construction or working. Where the fullest details are lacking, a general statement telling of endless trouble may have little value, because there is no uniformity among railways as to what is a failure. A meticulous report of every tiny defect or fault may give rise to the impression that the running shed staff are hard put to keep the units working, whereas on another line the same occurrences would be deemed unworthy of record. But practically every record of cars running in any numbers during the past four or five years shows that it is with relative infrequence that the main components such as the oil engine and the gearbox are responsible for an appreciable proportion of the failures. Usually such items as small pipes breaking or their connections loosening, electric insulation failures, seized clutches, run-down batteries, loosened bolts, foreign matter in small electrical auxiliary apparatus, are the origin of time spent in the shed, and considering the complication of controls and auxiliaries in a medium- or high-power car, the marvel is so few of the special and novel parts have given trouble. Multiple-unit and remote-control apparatus on the electric and electro-pneumatic principles is by no means so reliable as is necessary, and a striking improvement in reliability and in shed labour charges could be made by the elimination or drastic improvement of all forms of auxiliary electrical equipment. There is one encouraging feature of diesel car operation which in modern designs appears to be characteristic of a wide variety of types: that is, considerably less trouble is experienced by the running department after the vehicles have been at work for, say, 18 months or two years, due to the elimination of bad features in the design, to the increased experience of the shed staff, and to the building up of an organisation to promote efficient rostering and light and heavy overhauls of all parts of the car.

The Low-Power Railcar

IN both peace and war, on narrow-, standard-, and broad-gauge railways, there is an extraordinarily wide field for the railcar of less than, say, 100 b.h.p., and a field, too, which has scarcely been cultivated. Such vehicles have been the saviour of many small railways, and the remarkable performances put up during the last nine years by the 75 and 95 b.h.p. cars on the County Donegal Railways are a pointer to what may be done in the way of reducing operating expenses while giving greatly improved travel facilities to the public. There is no need for any refinements in such vehicles; indeed, it should be a *sine qua non* that there should be no refinements in the power, transmission, and control equipments, because of capital cost and of the more highly-skilled labour which would be required in the shed. At the present time, the value of such cars may be enhanced above that of improved service with low consumption of imported fuel, by the intelligent rebuilding of ordinary passenger coaches, for the great majority of car builders are not in a position to offer attractive delivery dates for a handful of special vehicles. The power of the cars envisaged may be anywhere between 50 and 95 b.h.p., and the seating capacity of the order of 50, and with the medium-speed (1,500-1,800 r.p.m.) lorry type of engine and a modification of lorry transmission there is no difficulty in making a satisfactory conversion, and one which will not entail maintenance costs above the average. It is not necessary to cut the weight to the bare bones in order to get a satisfactory power-weight ratio. A new car of 75 b.h.p. can be built to a tare weight of less than 10 tons, and to give $5\frac{1}{2}$ b.h.p. per ton of maximum laden weight, which is ample to maintain end-to-end schedules of 22-25 m.p.h. even with 1 in 50 grades, and can, indeed, look after trailer haulage. Moreover, should the imported fuel situation become worse, small cars are most amenable to producer-gas propulsion, the difficulties associated with satisfactory operation on gas increasing at a much greater rate than the engine size.

RAILCAR PROGRESS AND PRACTICE IN ITALY

About 750 diesel and petrol railcars are owned by the Italian State and private railways; they comprise standard-gauge and narrow-gauge vehicles for express, interurban, branch line, and rack railway operation, and which in the summer of 1939 covered approximately 90,000 miles a day

BEGINNING railcar traction about 14 years ago with a bare handful of miscellaneous vehicles, the Italian State Railways are now in possession of approximately 700 railcars with petrol and diesel engines, plus others which were ordered during the latter part of 1938 and the first half of 1939. After the early diesel cars, and within the last 10 years, well over 100 petrol-engined railcars, mainly of the Fiat type and with one or two engines, were built, but principally as a result of a collision involving a petrol car, when lives were lost through a fire, attention was concentrated upon oil-engined motive power, and this form has been universal for new cars until the experiments with producer-gas and methane since the beginning of the war. Railcar traction on a large scale began towards the end of 1933, and the first of the accompanying graphs shows the rate of increase over each year since that time.

Present Standard Cars

All cars are of the double-bogie single-unit type or of twin or triple articulated layout. Cars built and engined by Fiat[1] are the most numerous, but more than 100 Breda cars[2] with the A.E.C. type of engine have been acquired. Within the last two years other makers have come to the fore; for example, 50 cars built by the Officine Meccaniche, Milano,[3] were introduced during 1939. In the same year another 100 cars with bodies and chassis built by Fiat were ordered for delivery in 1940-41. Both these groups of cars are powered by the Saurer type of engine built by the licensee, the O.M. Brescia, and the latest development is 50 cars ordered in 1940 to be fitted with the Saurer BXD engine equipped with a Büchi pressure-charger to give a maximum output well in excess of 200 b.h.p., or more than 400 b.h.p. per car, as these vehicles, like all modern cars on the Italian State Railways, are to have an engine-transmission combination at each end. A few vehicles have also been built by Ansaldo, and equipped with that maker's new V engine, and it was a car of this type on which the first experiments with producer-gas were carried out. These cars, introduced first early in 1939, have 56 first and second class seats in an all-welded steel body 72 ft. long and on a tare weight of 29 tons; the top speed is 68 m.p.h. Power is provided by two Ansaldo eight-cylinder V engines with a top output of 130 b.h.p. at 1,400 r.p.m., and which are mounted on the bogies.

Transmission

Electric transmission was adopted, with two exceptions, for the few cars of the 1920's[4], but with the introduction of lightweight petrol cars in 1933 mechanical transmission was adopted, and perpetuated for hundreds of petrol and diesel railcars built until 1938-39. The Fiat cars have the maker's own four-speed gearbox; the Breda cars embody four-speed Wilson epicyclic gearboxes and Vulcan-Sinclair fluid couplings. With the introduction of the O.M. Milano type of car, a change was made to the Lysholm-Smith form of partial-hydraulic transmission and this is still the standard, being used in the last 100 cars ordered from Fiat, although the small number of Ansaldo diesel cars have been fitted with Mylius mechanical transmission. The nine Fiat triple-car high-speed trains[5] began their life with Fiat four-speed gearboxes, but at least one was subsequently equipped with a Cotal eight-speed box[6]; what type of transmission is now installed in these trains is not known. Gear drive is used also in the special twin-articulated double-engined 800 b.h.p. saloon built for State use. A special heating boiler is also installed in this official vehicle.

General Proportions

Both the Breda and Fiat standard cars are of light construction. The Breda cars of the first batch (23 vehicles) tared 20 tons, had two engines each set to give about 115 b.h.p., and had 56 seats. The first Fiat petrol cars tared only $13\frac{1}{2}$ tons, were powered by one 120 b.h.p. engine, and had 48 seats, but in subsequent orders the empty weight was increased to $14\frac{1}{2}$ tons only, although the seating capacity rose to 64 and the body was lengthened from $48\frac{1}{2}$ ft. to $57\frac{1}{2}$ ft. The first 10 Fiat diesel cars had two 80 b.h.p. engines, 56 seats within a length of $57\frac{1}{2}$ ft., and a tare weight of 18 tons; in another couple of years, when 100 cars were ordered, the weight had risen to $19\frac{3}{4}$ tons; a second and later order for 100 cars showed an empty weight of $21\frac{3}{4}$ tons, and when the design was developed to incorporate two 115 b.h.p. engines the weight was $23\frac{3}{4}$ tons, and for the cars with two 145 b.h.p. engines, first class accommodation only, and a buffet, the total was 28 tons. The O.M. Milano vehicles, with two 150 b.h.p. engines, 72 seats, and a

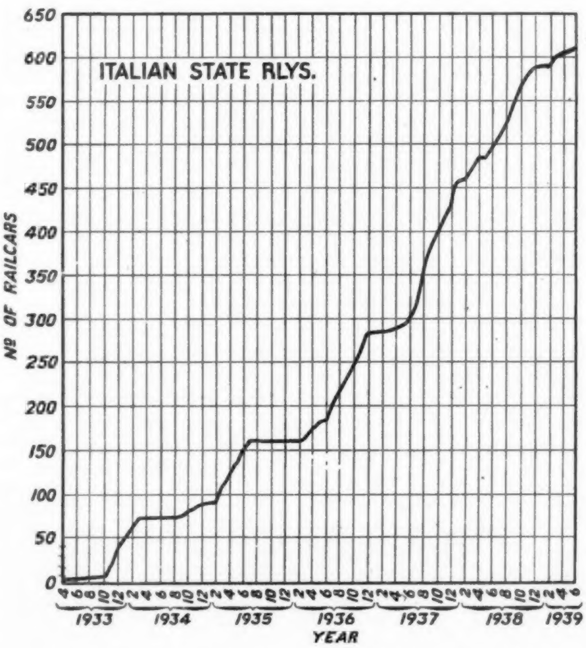


Diagram showing the growth in the stock of petrol and diesel railcars belonging to the Italian State Railways in the last seven years

length of 75 ft., tare about 30 tons, but the first three cars of 1937-38 had 130 b.h.p. engines. The weight of the cars now being built with pressure-charged engines will probably be about 34 tons.

Solo and Multiple-unit Working

A feature of I.S.R. practice has been that since railcar traction began to be taken seriously in 1933, trailer haulage has never been attempted. The petrol and diesel cars built up to 1937 were intended to work solo, but with increasing popularity and experience of working it was decided to equip subsequent cars for use in multiple-unit when desired, and many of the older cars have since been given the necessary apparatus. All the early cars were for branch and secondary line service, and the need for multiple-unit operation became more apparent when single-unit railcars were introduced on high-speed inter-urban services, such as Milan—Turin and Trieste—Venice—Bologna. The triple-car sets, with a designed top speed of 100 m.p.h., were intended more particularly for the fast Milan—Venice runs, but they have never been outstandingly successful. They tare only 82 tons and measure over 190 ft. in length, whereas the much newer twin-car State saloon, with the same engine output, has a length of 140 ft., a top speed of 84 m.p.h., and a weight of 80 tons.

The general top service speed of the single-unit cars is limited to 110 km.p.h. ($68\frac{1}{2}$ m.p.h.), and it has been found that rates up to the mile-a-minute range can be attained with safety by these vehicles on what would generally be considered secondary lines judged by Western European standards. The bogie cars intended for inter-urban express traffic are geared and powered to suit a top speed of 130 km.p.h. (81 m.p.h.); at the other end of the scale ten of the 230 b.h.p. Fiat cars intended for lines with steep grades have a top speed limited to 70 km.p.h. ($43\frac{1}{2}$ m.p.h.), and all four axles of the car are driven, contrasted with one axle on each bogie in the standard car.

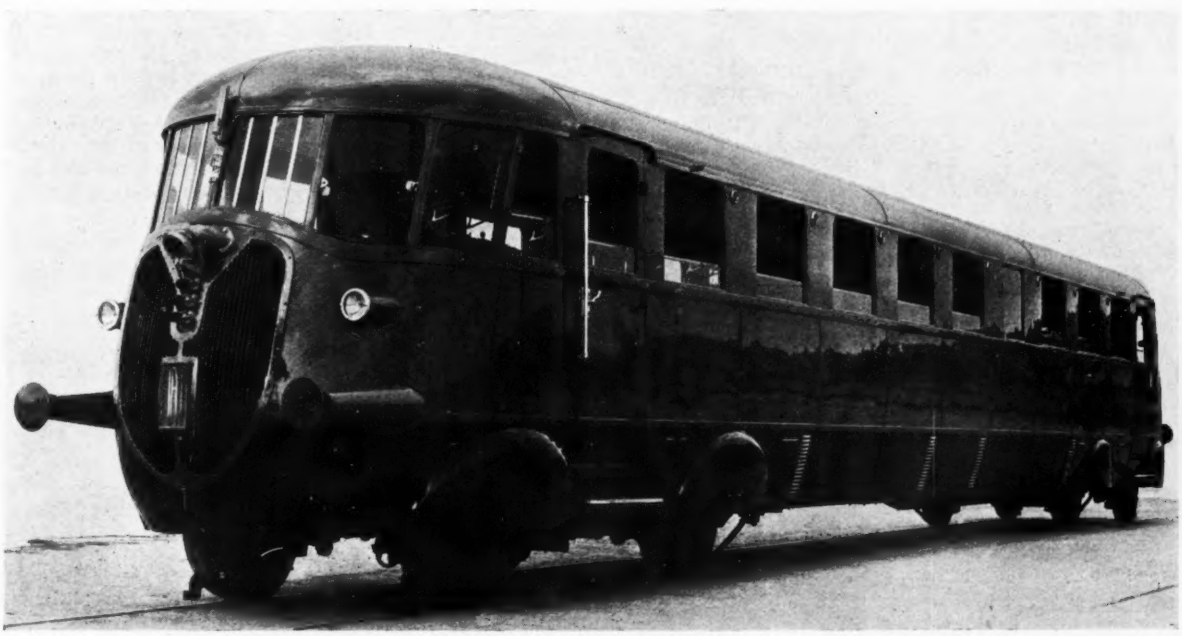
Railcar Services

During the first half of 1939, when railcar working reached its peak, local, stopping, semi-fast, and express services were being operated in great profusion, over nearly 150 lines extending from Merano in the north to

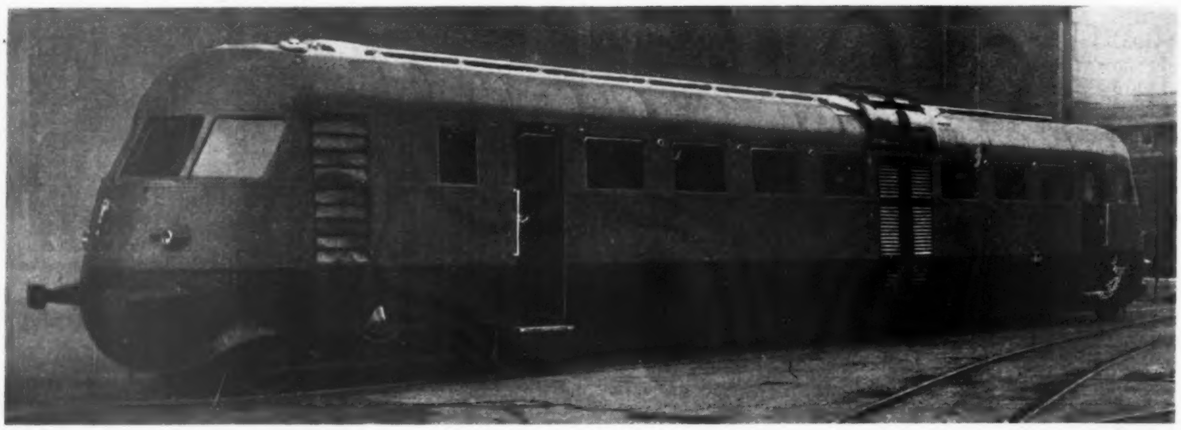
Graph showing the gradual rise of the daily railcar mileage, Italian State Railways, over a period of six years

Sicily in the south, and from Turin in the west to Trieste in the east, and including services over four lines in Sardinia, which saw diesel traction first with a diesel-hydraulic locomotives 15 or 16 years ago. On 19 lines all passenger traffic was operated by railcars. In the summer timetables of 1939 railcar working amounted to 73,000 miles a day, including several services at 60 to $65\frac{1}{4}$ m.p.h. start-to-stop, having risen to this figure from a daily mileage of 13,000 miles at the beginning of 1936.

The principal high-speed railcar services included four runs in each direction daily between Milan and Turin at 65·2 m.p.h.; Genoa—Milan, 93·2 miles, in 90-92 min. despite the ascent of the Giovi incline in the northbound direction; Bologna—Verona—Bolzano; Bologna—Venice—Trieste; Ancona—Bari—Brindisi, giving a much-needed acceleration—to 52 m.p.h. between Ancona and Bari—along the Adriatic coast line; Turin—Bologna; and Turin—Leghorn, connecting with a fast electric service to Rome. Actually the timetables for the summer of 1939 were



One of the modern Fiat 56-seater 230-b.h.p. fitted with couplings for multiple-unit working



Ansaldo charcoal-burning producer-gas railcar now running experimentally

almost entirely recast and, on the non-electrified lines, at least, to take full advantage of railcar potentialities. Consequently, additional to important interurban services as outlined above, practically every branch and secondary line was provided with quicker and more frequent services, with at least three or four trains a day in each direction, stopping at all stations yet maintaining end-to-end averages of anything from 30 to 40 m.p.h. On many lines, both important and subsidiary, the accelerated railcars ran in connection with the principal electric and steam expresses on the main lines.

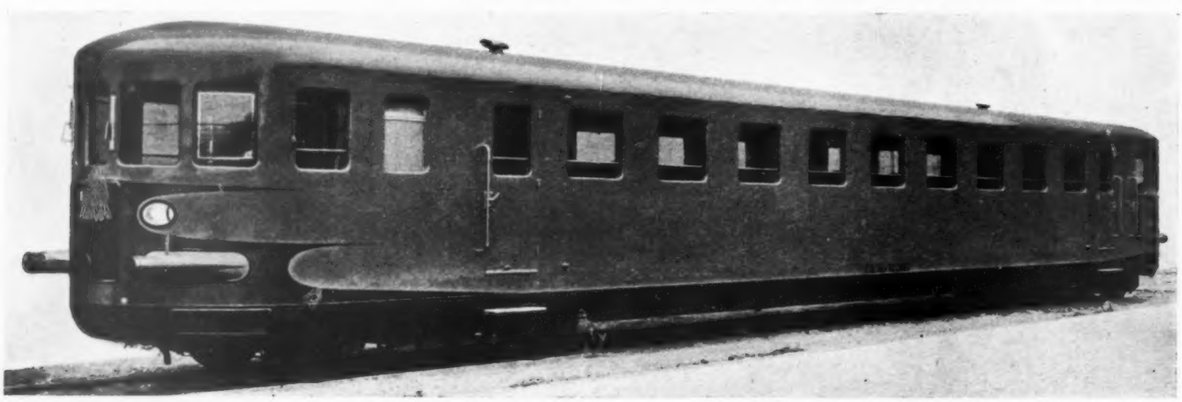
As far as possible the Italian State railcars are arranged to radiate from given centres. Although multiple-unit working of two cars by one driver is common practice, no attempt is made to operate traffic peaks of great magnitude by such means. Steam locomotives for freight traffic are still retained at the railcar centres, and these are used to haul augmented passenger trains at special holidays, the trains being made up of ordinary stock. In many instances some increase in the railcar schedule must be necessary, but it is claimed that no great trouble has been experienced in hauling these passenger trains at fairly high speeds with small-wheeled locomotives.

Producer-Gas Propulsion

Since the war the fuel position has brought about a considerable curtailment and deceleration of services, and attention has been turned towards producer-gas propulsion with charcoal-burning plants. One of the Ansaldo cars has been fitted with two producer plants located halfway along the car length, and accessible from the outside for cleaning and loading. The gas is led along cooling pipes located in a ventilated duct between ceiling and roof to filters and purifiers in the two engine rooms. The hoppers hold about 600 kg. (1,320 lb.) of fuel which suffices for runs up to about 250 miles. Some difficulty was experienced in evolving a charcoal-burning producer and auxiliary equipment which would satisfactorily feed an engine of the capacity of these Ansaldo units, which incidentally have had their top speed increased to 1,500 r.p.m., possibly in an endeavour to make up the power loss when working on gas, although such an increase will not raise the torque at low and medium engine speeds. But it is understood that the cylinder bore has also been increased slightly. The tare weight is 31 tons, or two tons more than the diesel model. Trials over the Milan—Genoa line showed that the 93½ miles could be covered in 90 min. with a running fuel consumption of 200 kg. (440 lb.) of charcoal per plant; a speed of 48-50 m.p.h. was attained up a 1 in 56 grade, and it was found that to maintain a speed of 70 m.p.h. along the level a charcoal consumption of 1½ kg. a km. (4·1 lb. a mile) was necessary.

Mileage and Maintenance

Taken over the whole stock, including vehicles under repair, the average daily mileage per car in 1938 was 125 miles, the upper and lower limits being 436 and 45 miles. The proportion of railcars normally held in reserve, and taken over the whole system, is about 18 per cent. A careful inspection and a minor overhaul is given to the engines every 20,000 miles, and the wear of the cylinders and bearings is measured in order to gain some idea as to whether at the end of the next 20,000-mile stage it will be



Prototype of the 50 Officine Meccaniche Milano 260-b.h.p. diesel-hydraulic railcars, Italian State Railways

Lines with Railcar Services, 1939, Italian State Railways

Turin—Alessandria—Bologna
Turin—Alessandria—Piacenza
Cecina—Grosseto
Rome—Civitavecchia Maritt.
Pisa—Leghorn
Grosseto—Leghorn
Turin—Milan
Biella—Santhia—Vercelli
Bologna—Padua—Venice
Milano(P. Genoa)—Vigerano—Alessandria
Milan(Cent.)—Tortona—Alessandria
Parma—Fornovo
Genoa—Tortona—Voghera—Piacenza
Piacenza—Bologna
Bolzano—Verona—Bologna
Bolzano—Merano—Malles Venosta
Venice—Mestre—Mogliano—Treviso
*Aidussina—Gorizia—Udine
Piedicolle—Gorizia Montesanto—Trieste(C. Marzio)
Divaccia (S. Canziano)—Erpelle Cosina
Trieste (C. Marzio)—Erpelle—Pola
Udine—S. Giorgio di Nogaro—Latisana
Udine—Palmanova—Cervignano del Friuligrado
*Palmanova—S. Giorgio di Nogaro
Trieste—Venice
Padua—Monselice—Mantua
Rimini—Ancona
Bologna—Castel Bolognese—Ravenna
Castel Bolognese—Faenza
Ancona—Pescara Cent.—Foggia—Bari—Brindisi
Taranto—Brindisi—Lecce
Fabriano—Porto Civitanova
Fabriano—Spoleto
Foligno—Spoleto—Orte
Ancona Marittima—Orte—Rome
Terontola—Perugia—Foligno
Pescara Cent.—Sulmona
Rome—Casino—Caserta—Naples
S. Maria a Vico—Valle Candina—Camillo—Naples C.
Benevento—Valle Candina—Camillo—Naples C.
Campobasso—Vairano—Naples
Formia—Sparanese—Capua
Avellino—Cancello—Naples
Rome—Vairano—Campobasso
Salerno—Battipaglia—Sicignano—Lagonegro
Battipaglia—Taranto
Catanzaro Marina—Metaponto
Taranto—Chiantona
Catanzaro Marina—Reggio di Calabria Succ.
Airasca—Saluzzo—Cuneo
Busca-Dronero
Savigliana—Saluzzo
Bestia—Mondovi—Cuneo
Chivasso—Asti
Castagnole—Alba
Cavallermaggiore—Moretta
*Asti—Castagnole delle Lanze
Casale Monferrato—Alessandria
Turin—Chivasso—Aosta
Chivasso—Casale Monferrato
Mortara—Casale Monferrato—Asti
Treviglio—Bergamo
Sondrio—Varenna—Monza—Milan
Seregno—Bergamo
Brescia—Cremona
Piacenza—Cremona
Cremona—Fidenza
Fidenza—Salsomaggiore
Fidenza—Fornovo
Pavia—Codogno—Cremona—Mantua—Monselice
Verona—Rovigo—Chioggia
Trento—Primolano—Bassano—Mestre—Venice
Bassano—Padua (*via* Camposampièro)
Schio—Vicenza
Vicenza—Treviso
Mantua—Suzzara—Ferrara
Verona—Mantua
Ferrara—Ravenna
Ravenna—Rimini
*Lavezzola—Lugo—Granarolo—Faenza
Ravenna—Granarolo—Faenza—Florence
*Ravenna—Russi—Lago—Faenza
Pontassieve—Borgo S. Lorenzo
Empoli—Siena—Chiusi
Pisa—Lucca—Pistoia—Florence
Leghorn—Pisa—Empoli—Florence
Viareggio—Lucca—Siena—Monte Anteco—Grosseto
Castelnuovo di Garfagnana—Bagni di Lucca—Lucca
Lucca—Pontedera
Pisa—Volterra
*Leghorn—Colle Salvetti
*Campiglia Marittima—Piombino
Porto Civitanova—Fabriano
*Urbino—Fabriano
*Viterbo—Attigliano
Rome—Viterbo
*Orte—Capranica—Civitavecchia
*Avezzano—Roccasecca
Rome—Fiumicino
Rome—Veletri—Fossanova—Terracina
Rome—Frascati
Terni Aguila—Sulmona
Sulmona—Carpinone—Vairano C.
Termoli—Campobasso—Benevento
Campobasso—Isernia
Benevento—Avellino—Cancello—Naples
S. Severino—Salerno
Codola Nocera Inf.
*Gaeta—Formia
*Formia—Sparanise
*Cancello—Torre Annunziata
Rocchetta—Avellino
Rocchetta—Spinazzola—Gioia
*Barletta—Spinazzola
Foggia—Manfredonia
*Foggia—Lucera
*Cerignola Campagna—Cerignola
*Margherita di S. Ofantino—Marg. di Savoia
Foggia—Rocchetta S.A. Potenza
S. Eufemia—Catanzaro Marina
Paola—Cosenza
Sibari—Cosenza
Roccapalumba—Agrigento C.
Caltanisseta X.—Agrigento

Sicily:
Syracuse—Canicatti
Alcamo—Trapani
Catania—Caltagirone
Catania—S. Maria Schettino
Messina C.—Syracuse C.
Messina C.—Palermo C.
Catania C.—Palermo C.
Palermo C.—Trapani

Sardinia:
Cagliari—Terranova P.
Porto Torres—Chilvani
Iglesias—Cagliari
*Golfo Aranci—Terranova P.

* All passenger services worked by railcars

necessary to give a more comprehensive overhaul. According to the date and type of the car, heavy overhauls are given to the engine every 62,000 to 155,000 miles, the engine and transmission then being dismantled and checked. Simpler inspections are given to the whole car every 2,500 miles. In general, heavy overhauls are concentrated at the Florence workshops.

According to the estimates made in connection with the first lightweight cars of 1933-34, the life of the car was taken as only six years, equivalent to about 300,000 miles, but experience has shown that these particular types will have a life of at least eight years, at which period amortisation is now reckoned in the account sheets of more modern cars. But it is realised in Italy that with the maintenance and heavy repair methods and organisation now built up, railcar life will appreciably exceed this figure, and that before the condition becomes bad enough for scrapping the railcar will be obsolete.

Operating Costs

Taken over the stud of Fiat and Breda diesel cars working in traffic other than high-speed interurban, and comprising about 300 vehicles, the working cost during 1938 averaged 2·35 lire per railcar-km. including maintenance, repair, and depreciation. The capital cost of a car is given as 480,000 lire and amortisation charges are based on a life of 8 years. Details of the cost of operation are:

	Lire
Driver's wages	0·35
Fuel	0·27
Management and service in sheds	0·14
Lubrication and sundry materials	0·05
Maintenance...	0·85
Depreciation and renewal...	0·69
Total, per km.	0·235

The guard's wages are not included in the above table. A two-coach steam train has a corresponding operating cost of 4·92 lire per km., the life being taken as 30 years, and the purchase price of locomotive and stock at present prices as 1,609,000 lire. The low value of the railcar capital cost compared with that of the steam train is due largely to the number of cars ordered at one time—batches of 100 have been ordered twice—and to the fact that there are only two main standard types considered above.

In high-speed interurban traffic the 25 Fiat 290 b.h.p. cars with first class accommodation and a buffet average 2·67 lire per km. made up as follows:

	Lire
Driver's wages	0·25
Fuel	0·42
Management and service in depots	0·14
Lubricants and sundry stores	0·05
Maintenance...	1·00
Depreciation and renewal...	0·81
Total, per km.	2·67

The wages of the guard and buffet attendant are not included. The purchase price of a car is 630,000 lire and amortisation is calculated on an eight-year life. An express steam train with six carriages headed by a Pacific locomotive costs 7·98 lire per km.; but of course has a far greater number of seats which—in cost per seat—more than offsets the distance. With the local and stopping cars the greater seating capacity of a two-car steam train cannot be said to offset cheaper working cost per km., although the figure per seat-mile is only 0·028 lire compared with 0·42 lira, because with railcars it has become the practice to give a faster and more frequent service.

Private Lines

Although a number of the smaller lines such as the Pisa—Pontedera use handfuls of Fiat diesel cars, the principal private owner is the Calabra-Lucane Railway, which in 1924 introduced a mobile power house for steep-grade working, and now has over 40 cars. The principal types are double-bogie 260 b.h.p. stainless steel units[7]; 100 b.h.p. four-wheel rack-and-adhesion vehicles[8]; and 130 b.h.p. four-wheel stainless steel rack-and-adhesion cars[9]; all have electric transmission. Bigger cars, to have a Saurer 300 b.h.p. engine, are on order.

Diesel Traction Supplement
[1] October 30, 1936.
[2] March 22, 1935.
[3] March 18, 1938.
[4] July 14, 1933.
[5] November 27, 1936.
[6] May 13, 1938.
[7] June 12, 1936.
[8] July 12, 1935.
[9] January 20, 1939.

DIESEL SHUNTING OPERATION IN SUDAN

By J. D. YORK, A.M.I.M.E., Locomotive Running Superintendent, Sudan Railways

The 3 ft. 6 in.-gauge Sudan Railways, with 2,325 miles of route, have 32 shunting locomotives, of which three are diesel. Shunting attains appreciable proportions only at three stations: Port Sudan (with 10 engines), Khartoum (with seven engines), and Atbara (with six engines). The mechanical department personnel numbers about 6,000, supervised by a hundred British officials under the direction of Mr. J. H. Dunbar, the Chief Mechanical Engineer. The locomotive running section accounts for about a third of the personnel, the steamship section for a third, and a third is in the locomotive, carriage, wagon, and electrical section. There is no local or suburban traffic in the country, and consequently there is but limited scope for railcars.

FIVE diesel locomotives are owned by the Sudan Railways. Two of them are Hawthorn-Leslie four-wheelers with 90 b.h.p. McLaren engines, which are used to haul the annual cotton crop on the 2-ft. gauge 20-mile Tokar-Trinkitat branch; one is a 225 b.h.p. Harland & Wolff diesel-mechanical shunter; and two are English Electric 350 b.h.p. shunting locomotives. All the following particulars relate to the two English Electric locomotives, Nos. 401 and 402, which are to the maker's standard six-wheel design adapted to the 3 ft. 6 in. gauge. The mechanical portions are of Hawthorn-Leslie manufacture. The two end axles are driven by nose-suspended traction motors, and the centre axle by coupling rods. From being put into traffic during the autumn of 1936 until the end of 1939, No. 401 had given 16,100 service hours and No. 402 about 13,800 service hours.

The Locomotive Design

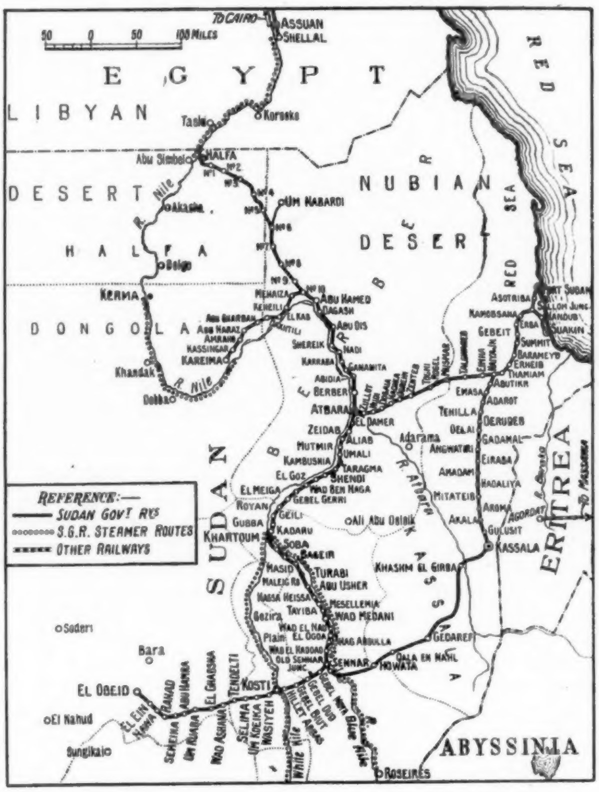
A brief recapitulation of the leading features of these two locomotives is not out of place here. The 51-in. wheels are spread over a base of 11 ft. 6 in. and the overall length is 28 ft. 10½ in.; the maximum width is 10 ft. 2 in. and the height 12 ft. 9 in. The working order weight is 45 tons and the starting tractive effort 30,000 lb., giving a factor of adhesion of 3·35.

Power is obtained from an English Electric K-type engine set to give 350 b.h.p. at 685 r.p.m. in six 10 in. by 12 in. cylinders, and mounted complete with the main generator, on a three-point system. The engine speed is controlled from either of the two master controllers by means of solenoid-operated valves which admit lubricating oil under pressure to cylinders incorporated with the governor, giving this an appropriate setting.

Cooling water is circulated through a radiator by means of an engine-driven pump, and the radiator is cooled by a motor-driven fan thermostatically controlled by the temperature of the water and engine lubricating oil. A mechanically-driven pump supplies lubricating oil to the engine and also circulates it through a separate section of the radiator. Temperature gauges are provided for both lubricating oil and cooling water. On light loads the engine is prevented from attaining an excessive speed by the mechanical governor, and on heavy loads the English Electric torque-control system limits the power taken by the main generator from the engine to a value within the capacity of the engine, thus preventing overloading.

Electrical Control

A 230-kW 700-volt generator supplies current to two traction motors which drive the locomotive through gear wheels pressed on the leading and trailing axles. As the master controller is notched up the speed of the traction motors increases with the engine speed, due to the successive increases in the voltage of the main generator. When full



Map of the Sudan Railways system; all the lines shown are 3 ft. 6 in. gauge. The Tokar-Trinkitat branch is just south of Suakin

engine speed is reached further acceleration of the locomotive is obtained, firstly by changing over the traction motors from series to parallel grouping, and secondly by shunting the fields of the traction motors. The traction motors are force-ventilated, the air being supplied by an electrically-driven blower.

An auxiliary d.c. generator mounted on an extension of the main generator shaft supplies current for the excitation of the main generator fields and feeds the control circuit and electric motor for driving the vacuum brake exhauster, and also, during normal running, supplies a 40-cell battery with charging current. To start the engine, the battery is connected across the main generator, causing it to run as a motor and rotate the engine until firing commences. In addition, at low engine speeds, the battery shares the

auxiliary load with the auxiliary generator, the latter taking over this load automatically when the engine speed is raised sufficiently to increase the auxiliary generator voltage to 85.

The various electrical switching operations necessary for controlling the locomotive during running are brought about by the notching of the master controller handle. The arrangement of connections in the master controller with the reverse handle in the off position enables the engine, when desired, to be run up to speed on no load without obtaining a high voltage on the main generator and without energising the traction motors.

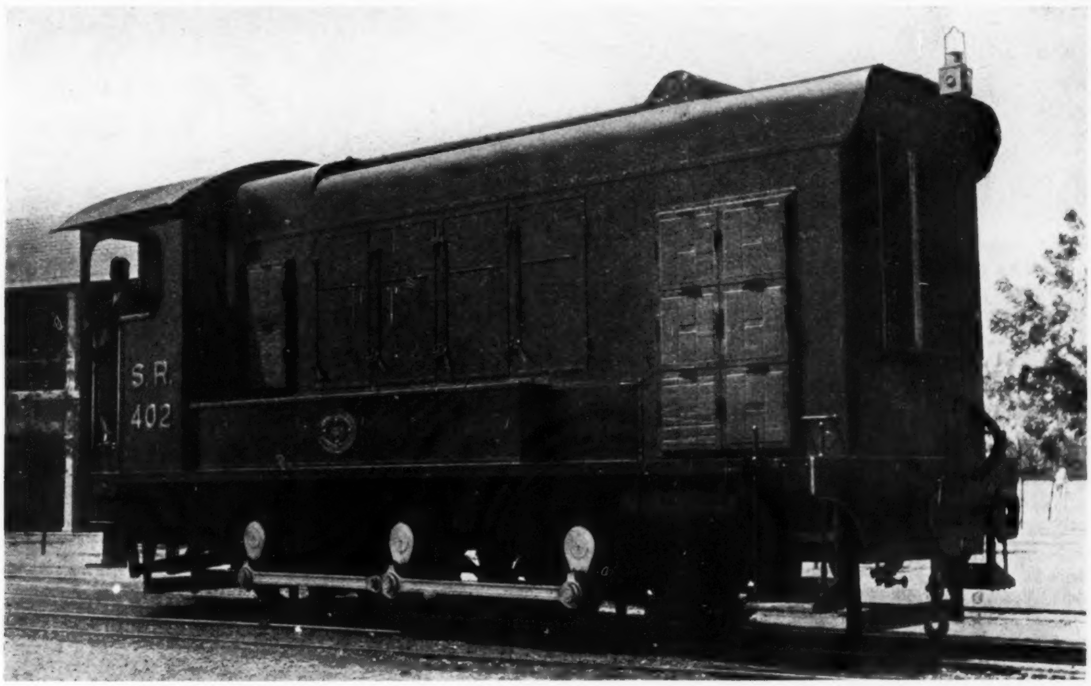
Push-buttons are provided so that the engine can be started and stopped from the driving cab or the engine room, and labelled switches are provided in the control compartment for switching the exhauster and control circuits on or off. Motor cut-out switches on the main control frame allow a defective traction motor to be cut out of circuit when necessary, while still permitting the operation of the remaining motor, and a charging switch on the control frame affords a means of adjusting the auxiliary generator voltage and battery charging rate to suit varying service conditions. With one motor cut out the maximum current in the main generator is limited to about three-quarters of its normal peak value.

Service Operation

When the English Electric locomotives arrived in the country they were based on Atbara for running initial trials. After working satisfactorily for several months both locomotives were transferred to Port Sudan, where shunting engines are employed on heavier and more continuous shunting than in Atbara. Each diesel locomotive works 24 hr. a day for six days a week and the crews are changed over every 8 hr. On the evening of the sixth day the locomotives are brought to the running shed and on the following morning, when the engines have cooled down, a weekly inspection is made and the locomotives are returned to service the same day.

Both locomotives work in the quay yards at Port Sudan, where they are employed in splitting up arriving trains, making up trains for departure, and placing and withdrawing wagons in various goods sheds and under the dock cranes. The speed of movement of these locomotives is more rapid than that of steam shunting engines, and owing to their greater regularity of acceleration there is less violent buffering up and a more regular drawbar pull is obtained. This tends to reduce damage to rolling stock and their contents. During normal working the locomotives are called upon to handle maximum loads of about 900 tons, and such weights are hauled without difficulty.

When working, the locomotives are in the charge of Sudanese shunting drivers or passed main-line firemen, who were easily trained in their new duties. It has not been found possible to operate the locomotives with only drivers on the footplate and a mate has had to be provided for look-out purposes when working over running lines and in the congested quay areas at Port Sudan.



350 b.h.p. English Electric shunting locomotive at Port Sudan, on the Sudan Railways

Shed Maintenance

When the locomotives were first put into regular service at Port Sudan, one hour each day was allotted for inspection by a Sudanese fitter and Sudanese electrician. This was found to be unnecessary and has been discontinued, but drivers report any defects they find during their turns of duty. Routine shed inspections are carried out weekly and after every 1,000 running hours.

During the weekly inspections the engine is run for a few minutes to examine the fuel and lubricating oil systems for leaks and for checking each cylinder to see that they are firing correctly. Valve clearances are checked and re-set if necessary. All oil pipe unions and main-bearing and big-end bolts are inspected for tightness. Oil is pumped by an auxiliary hand pump to the main and connecting-

rod bearings to check that there is a good flow of oil. The fuel oil and main lubricating oil strainers are cleaned. Three of the six air filters on the engine are removed in rotation each week for cleaning, and the dry fabric air filter panels in the walls of the engine room are taken down and gently tapped to remove dirt. Inspection is made of commutators and brush gear of the traction motors, main, auxiliary and torque-control generators, and the fan, blower and exhauster motors. All contactors are examined, clearances checked, and burnt tips cleaned up where necessary. The control equipment is carefully inspected, drum segments cleaned, finger tension checked, and other electrical apparatus thoroughly cleaned. The voltages and specific gravity of the battery cells are recorded, distilled water added if required, and an external charge applied when necessary.

During the inspections after 1,000 running hours, which are arranged to coincide with weekly inspection, the following work is carried out. Fuel oil injector nozzles are removed for cleaning and testing and set by means of a hand pump to blow off at a pressure of 1,500 lb. per sq. in.; the exhaust valves and cages are removed for cleaning and the valves ground in when necessary. The camshaft is inspected and the timing chain tested for tightness. The oil and water radiators are cleaned and the rotary vacuum exhauster is stripped down and decarbonised. During every alternate 1,000 hours inspection, the inlet valves and cages are removed for cleaning and the valves ground in when necessary. The same procedure is followed for inspecting the electrical apparatus as for a weekly inspection, but it is more thorough as extra time is allowed, usually about three days.

General Overhaul

After approximately every 5,000 running hours each locomotive has been brought into the main railway works at Atbara for a general overhaul. On these occasions very few repairs have been found necessary and the work done has been more in the nature of a general inspection than an overhaul. Both locomotives have had two general overhauls and the major items of interest during these overhauls have been as follows:—

(*a*) All essential moving parts were dismantled for inspection and replacement where necessary.

(*b*) All big-end bearings were inspected and clearances checked. One bearing has been renewed.

(*c*) Alignment of the crankshaft was checked and the bearing clearances measured. It has not been found necessary to remove the crankshaft, but selected bearings have been removed for inspection.

(*d*) Fuel pipes were tested and injector pressure set.

(*e*) New small end bushes have been fitted where necessary.

(*f*) During the first overhaul the top piston ring in each cylinder was renewed and during the second overhaul all piston rings were renewed.

(*g*) Blades of the vacuum exhauster were renewed.

(*h*) Bore of each cylinder was measured, ½ in. below top of piston ring travel, for record purposes.

(*i*) All electrical equipment was inspected and tested, and as far as possible all parts were restored to the same serviceable condition as when new. Particular attention was paid in examining terminals, connections, and cables for chafing.

(*j*) Traction motor bearings were re-packed with wool and oil.

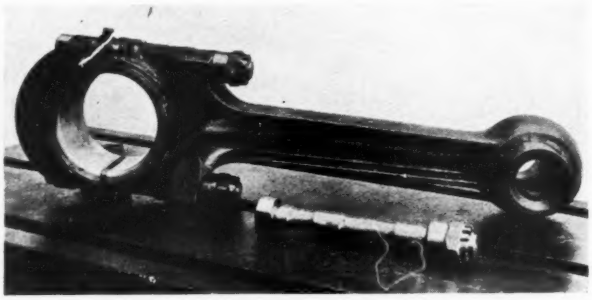
(*k*) Axleboxes, side rod bushes and wheels were examined. During the first overhaul these items required no attention, but during the second overhaul the side rod bushes were remetalled, tyres were turned, and new axlebox side liners were fitted.

During the second general overhaul of each locomotive the flanges of the centre wheels were removed to reduce flange wear on the other tyres. This has been most beneficial; the engines go round curves more easily and the flange wear on the leading and trailing wheels is much reduced.

When the locomotives were ordered, a maximum speed of 35 m.p.h. was specified so that, if necessary, the engines could work local main-line trains. To obtain this speed the traction motors are changed over from series to parallel running when the master controller handle is in the sixth notch, and the seventh notch shunts the fields of the traction motors. After the locomotive has been running in the sixth and seventh notches, the parallel connection and the field shunting connections of the traction motors are retained on all intermediate notches until the controller handle is returned to the off position. As the locomotives have only been used for shunting, the sixth and seventh notches have been blanked off to avoid possible damage through drivers not returning the controller to the off position after running in the sixth and seventh notches.

Steam and Diesel Comparisons

In making comparisons between diesel and steam shunting locomotives the main aspects to be taken into consideration are: shed maintenance and operating costs, initial cost, availability, and heavy overhauls. Records have been kept of the maintenance and working costs of the locomotives, and it is estimated that under the operating



Connecting rod and a big-end bolt of the 350 b.h.p. K-type English Electric engine.

conditions at Port Sudan, the diesel locomotives show a saving of 52 per cent. compared with other steam locomotives doing similar work. In making this comparison there have been taken into consideration fuel, lubricating oil, water, maintenance, labour and stores.

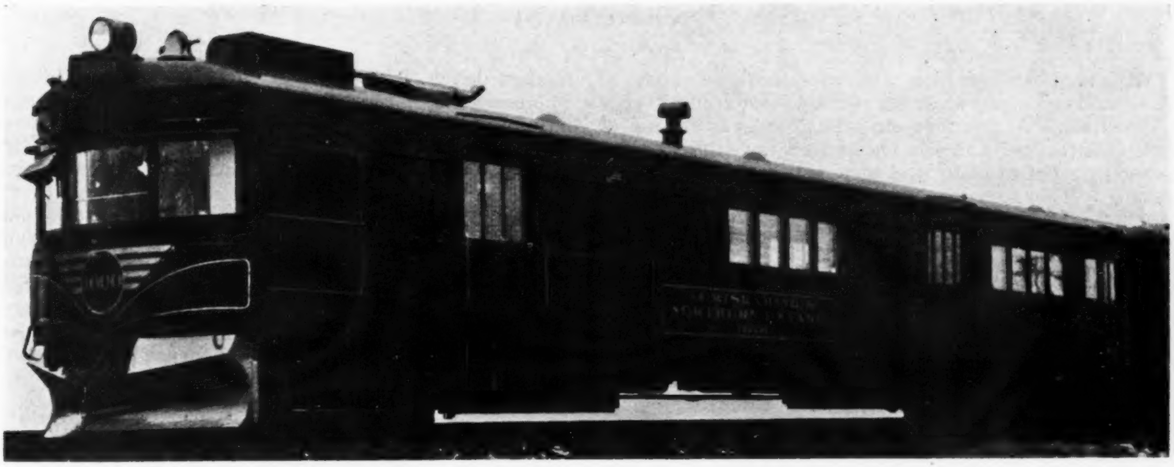
The initial cost of a diesel is considerably higher than that of a steam locomotive, and on the assumption that a diesel will not have a longer life than a steam locomotive, the depreciation charges should be higher. At present it is not possible to say what the depreciation should be, as the total life of a diesel locomotive cannot be gauged accurately enough, as yet, for generalities.

The availability of the diesels has proved to be greater than that of steam locomotives as time is saved on refuelling, watering, fire-cleaning and repairs. The periods between heavy overhauls have been approximately the same for the diesels and steam locomotives, but the costs for the former have been considerably lower. The cost of the second heavy overhauls of the diesels compared with the cost of an overhaul to a steam locomotive was about 60 per cent. less, and the general indication is that the cost will still be lower even when the locomotives have been in service for a longer period.

In these comparisons between diesel and steam locomotives there are two important facts to be taken into consideration. First, the diesels are new, but the steam locomotives have been in service for several years; secondly, the normal running shed staff can deal adequately with the maintenance of a steam locomotive, and they can be trained in the routine maintenance of a diesel, but skilled electricians and experienced diesel fitters must be at hand to deal with defects in a diesel locomotive which cannot be easily diagnosed.

REBUILT DIESEL TRAIN IN CANADA

Passenger, parcels and milk traffic handled on short branch line in Ontario province



The three-car 250 b.h.p. standard-gauge set of the T. & N.O. Railway

THE Temiskaming & Northern Ontario Railway has recently placed in service between Cochrane and Porquis a diesel-electric passenger train consisting of a combination baggage car and power unit ; one second class car with small baggage compartment ; and one first class car. The combination baggage car and power unit was converted from a Brill 73-ft. gas-electric car built in 1926, the gasoline engine of which had become obsolete. It was decided to replace this engine with a modern oil engine, and a Cummins six-cylinder 250-b.h.p. engine running at 1,000 r.p.m., and adaptable to the existing electrical equipment in the car, was selected. The new engine, connected through a flexible coupling to the original generator, is mounted on a common steel bedplate welded to the car centre sills. The frames of the engine and generator were secured to the bedplate by means of fitted bolts, and the whole forms a rigid and vibration-free mounting. To prevent the vibration existent in the original car, a ⅜-in. cover plate was riveted from bolster to bolster on the bottom of the centre sills. The starting equipment for the engine is of the compressed air type, and consists of a small petrol-driven compressor, charging a reservoir to a working pressure of 350 lb. per sq. in. All the electrical equipment was given a thorough overhaul and no major replacements were required, as it was found to be in first class condition. Since being replaced in service the Westinghouse electrical equipment has proved to be entirely satisfactory. Train lighting is provided by the generator exciter at 30 volts, and a set of lead-plate cells is carried underneath the power car and charged by the exciter.

Rebuilding and Accommodation

In rebuilding the power car, all the passenger seats were removed and the entire space, except the power compartment, was made into a baggage and express car. To speed up the handling of baggage and express, two additional baggage doors were provided in the body of the car. A number of windows in the part formerly used as a passenger compartment were blocked up. The car roof and sides were insulated with 2-in. salamander and then finished with ⅞-in. sheathing ; the interior finish is in grey. The trailers were originally two separate storage battery cars built in 1924. After many years of service these cars, owing to greatly increased traffic demands, were removed from service and placed in storage. In the spring of 1939, their use was considered as trailers, and after considerable rebuilding they have proved satisfactory. These cars were built in order that they could be operated from either end, which meant that in the rebuilding new vestibules, complete with standard buffing gear and diaphragms, were required. It was further necessary to raise the car body nearly 6 in. in order to bring the platforms to the standard height. In the case of the first class car, the entire end of this car had to be rebuilt, as the end was a blind-end baggage compartment. Both cars were equipped with water-raising systems, and other modern toilet facilities. Heating of each of the two cars is accomplished by means of a hot-water heater supplying heat through fin-type tubing. All ceilings, walls, and floors have been thoroughly insulated with salamander. The interior finish comprises cream ceilings, light grey upper walls, black window frames, and blue lower walls ; the floor is painted terra cotta. The second class seats are covered with black Pantasote and the first class seats in blue plush.

Service

Normally, the triple set works alone, but during the Christmas season it was found necessary to handle a fully-loaded standard steel car of about 75 tons total weight, and the diesel-electric was able to handle the extra tonnage in a most satisfactory manner. The average mileage a day is 157¼, and over a 30-day period the fuel and lubricating oil expenses amount to about $270, equivalent to 5·73 cents a mile ; the fuel oil is 14 cents a U.S. gal. and the lubricating oil 68 cents a U.S. gallon. Petrol used for the starting compressor engine amounts only to 13 U.S. gal. a month. Duty on weekdays comprises three trips each way over the 28¼-mile line between Porquis and Cochrane ; on Saturdays and Sundays there are two trips a day each way.

WELDED JOINTS IN RAILCARS

A discussion of the details of types available for body and underframe structures

By O. BONDY

THE high cost of tools and equipment necessary to produce steel pressings suitable for railcar constituents is a serious obstacle to the general use of such construction, and has encouraged the fabrication of components out of plain steel plate with the aid of electric welding. The numerous shapes which are so produced without difficulty are technically faultless, and represent the highest attainable development in steel construction. If this plate girder type of work is compared with the older forms its great superiority is perceived. Such an arrangement is alone able to meet in the fullest manner the requirements to which all such work is subject in practice, *viz.*, the forces must be distributed throughout the various constructional parts with the maximum permissible stresses evenly distributed; elongation characteristics must be the same in all parts; and the forces must be transmitted without tendency to buckling. In addition to its technical advantages the welded steel plate girder form of construction is also economical. For this reason it has been widely applied in diesel railcar work.

Fig. 1 shows the gradual course of development of lightweight construction from the riveted form to the modern design, in the case of the side walls of a vehicle. The connecting pieces in *b* and *c*, being welded, represent an advance on the riveted form seen in *a*; but the design shown in *d*, in which the side wall verticals are not carried past the underframe girders but are butted against them, is really the only one which, on account of the weight saved and the perfection of the welded formation, may be regarded as completely satisfactory. The development of the means of joining the side wall of the vertical to the steel sheet wall is also of interest; the arrangement illustrated in Fig. 1 is alone economical and hence really satisfactory, for it avoids all duplication of cross section in the material, inasmuch as the sheet metal is only welded to the edge of the side-wall vertical, which is itself formed of sections, and the outer wall acts to some extent as the second limb of a U-section.

Welded Seam Positions

Items *a* and *b* in Fig. 2 show girder joints, as they were made in the early days of the arc-welding process, and derived from the preceding riveted forms. These joints failed as the welded seams were in unfavourable positions.

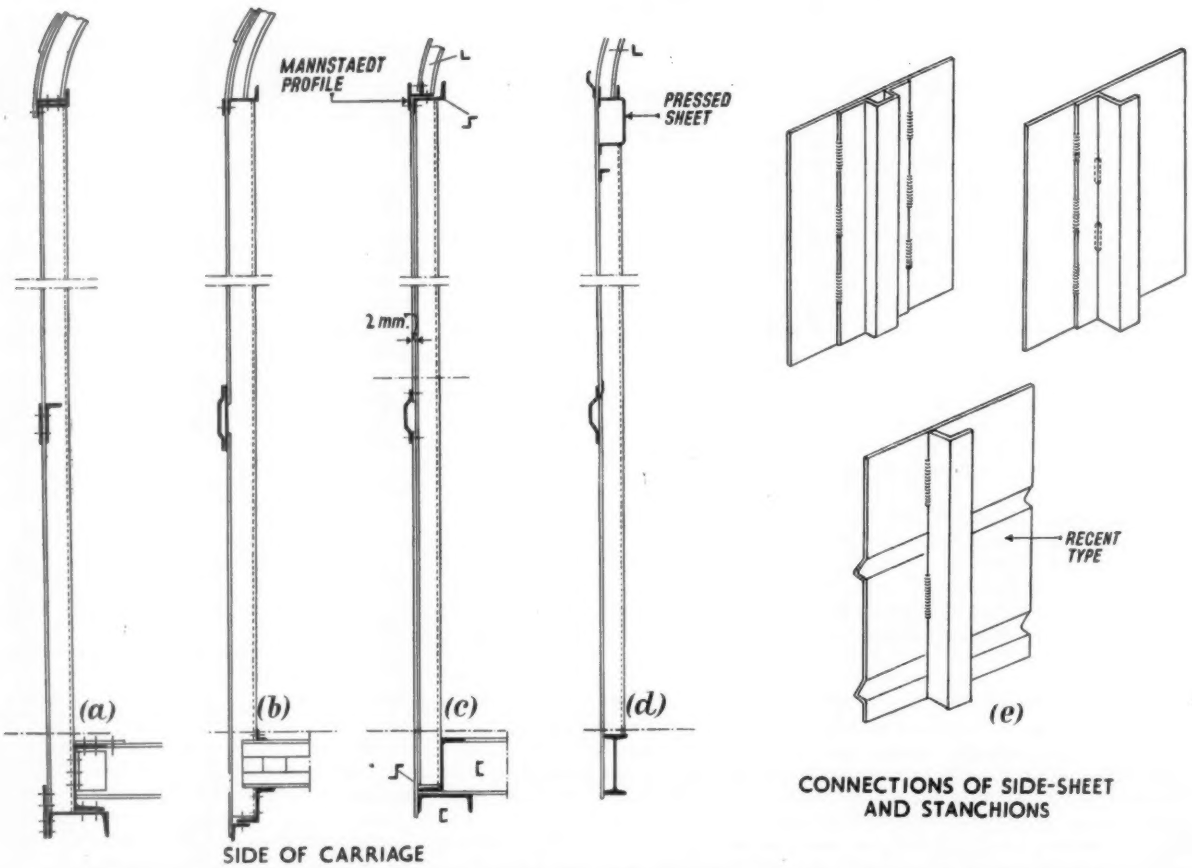


Fig. 1—Development of welded construction for the pillars, cantrails and side panels of coaching stock

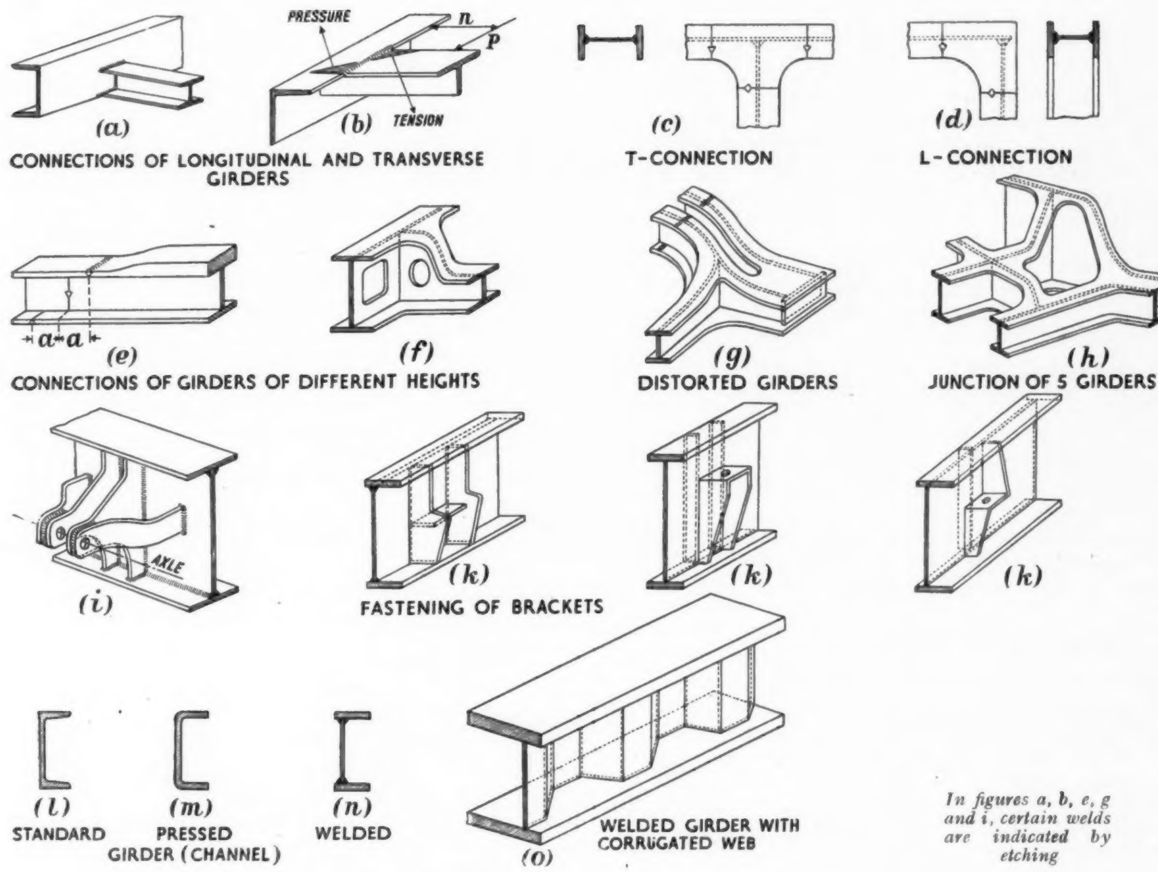


Fig. 2—Various forms of welded joint for the body and underframe structure and the engine baseplate of railcars

In the case of *b* the weld not only failed on account of the stress at that point, but the opening-out effect at the end of the seam was bound to injure it. Examples *c* to *k* show arrangements which are sound from the welding point of view. The welded seams are situated, as a matter of principle, at unimportant places, as for instance, the longitudinal seams between the girder flanges and webs, and at most, straight tension or compression loads are applied to them as in the case of butt-welded seams, which are now being generally used.

Butt Seams

Butt seams are being adopted, without adding to the total weight, at points subjected to less stress, and are free from the moments of internal stress met with in fished joints or direct joints between cross sections. Such corner joints are strengthened in the plate girder type of construction by rounded gusset plates, which run into the upper or lower flanges of the longitudinal or cross members. Butt-weld joints covering the complete cross section of a girder are thus avoided, their individual plates being brought into contact and welded at certain selected points, as in Fig. 2*e*. Figs. 2*f* to 2*k* clearly show how simply the forces involved are transmitted without tendency to buckling. This is not attainable with rolled section materials, whereas in plate girder construction the forces can be made to meet the loads involved by gradually increasing the plate dimensions.

Considerable experience has been obtained in this respect with the joints in welded carrying frames for oil engines. The plate type of construction has enabled solutions to problems to be obtained analogous to the phenomenon of organic growth in the plant world; the branch springing out from a tree trunk illustrates the essential features of modern welding construction, namely, a gradual distribution of the paths of force, steady variation in cross section, and joints rounded off with equally-distributed elongation characteristics. Figs. 2*i* to 2*k* also illustrate details of engine carrying frames.

Items *i* to *o* in Fig. 2 show the evolution of the various forms of girder from rolled steel sections down to the plate type with thin corrugated sheet web, resembling the prototype met with in aeroplane construction. Such girders have been adopted for the steel engine-carrying members on the hydronalium cars of the German State Railway (see issue of this Supplement for December 23, 1938).

As an example of the weight which can be saved by welding may be mentioned a bogie railcar weighing 39·8 tons when of riveted construction, the mechanical portion accounting for 33·3 tons. By the adoption of welding and the introduction of the special shapes which welding permits, a saving of about 3¼ tons has been made in the mechanical portion, equivalent to about 10 per cent. Such a saving is not to be compared with that gained by using high-tensile alloy steel, but is nevertheless a useful contribution, which saves power, and thus fuel and money, throughout the life of the car.

NOTES AND NEWS

D.E.U.A. Bulletin.—The 1939 Bulletin of the Diesel Engine Users Association was read and discussed in London on April 11. The Bulletin includes a brief section on rail traction.

Hydraulic Transmission.—A further development in hydraulic transmission intended more particularly for vehicles which start and stop frequently has been patented (No. 517989) by Mr. Harold Sinclair and Mr. A. Basbe. One of the principal features is a rapid discharge scheme for the liquid to enable easy gear engagement from rest, and the ensemble is on the usual turbo principle.

Oil Cleaning Plant.—A new automatic lubricating oil purifier of the Fox type has been developed recently by J. Glover & Sons, Ltd., of London, S.W.8, and operates on the washing principle with warm water containing a chemical named Foxite. This is passed through the oil, picking up all the foreign matter, and depositing it at the bottom of the container.

Compressed-Gas Locomotive.—The Leipzig gas works has in service a small four-wheel shunting locomotive capable of dealing with 20-wagon (say 400-ton) trains, which is powered by a Deutz diesel engine modified to use town gas stored at high pressure in four cylindrical bottles. It has been claimed that service up to the equivalent of a 30-mile run can be obtained on one charge.

Dr. J. Rónai.—Dr.-Ing. Julius Rónai, the well-known consulting engineer to Ganz & Co. Ltd., who was previously with the Hungarian State Railways, has been made a Commander of the Order of Sava by the Prince Regent of Jugoslavia in recognition of his work in railway engineering, more particularly by his investigations into the security of narrow-gauge rolling stock on the 750-mm. (2 ft. 6 in.) gauge line between Belgrade and the Adriatic.

New Latvian Railcar Train.—The Latvian State Railways recently rebuilt from ordinary coaches a three-car articulated diesel train. It operates on the 750-mm. (2 ft. 6 in.) gauge and has a top speed of 43 m.p.h. Power is provided by two 100 b.h.p. Mercédès engines driving two axles through Mylius mechanical transmission. All the power equipment is mounted on a short centre vehicle which is supported on two pivots cantilevered from the inner ends of the near supporting bogies of the outer cars. Seats are provided for 98 passengers within a total train length of 107 ft.

Diesels and Railcars in Algeria.—The Algerian Railways have in service 100 b.h.p. Berliet and 110 b.h.p. Renault four-wheel petrol cars dating from 1926-27; several four-wheel French-built diesel cars of 80 to 100 b.h.p. built in the years 1932 to 1937; some 600 b.h.p. Renault twin-car diesel sets; three 600 b.h.p. Saurer-engined diesel goods and baggage cars with special passenger trailers; and a few Michelin 96-seat pneumatic-tyred railcars with petrol engines. There are also two diesel locomotives, one of 700 b.h.p. and the other—now in course of rebuilding—of 920 b.h.p.

American News.—The 1940 budget of the Chicago, Milwaukee, St. Paul & Pacific Railroad includes an allowance for the purchase of 18 diesel-electric locomotives. The orders for these have been split up as follows: Electro-Motive Corporation, twelve 600 b.h.p.; Alco, one 1,000 b.h.p. and two 600 b.h.p.; Baldwin, one 600 b.h.p. and one 300 b.h.p.; G.E.C., one 360 b.h.p. It is understood that all of these will be acquired on the hire purchase system. Five more diesel Rocket trains are to be acquired by the C.R.I & P. Railroad; three will have 2,000 b.h.p. Electro-motive locomotives and two will have 1,000 b.h.p. units. They are to be used between Memphis (Tenn.) and Amarillo (Tex.); Kansas City and Colorado Springs; and St. Louis and Minneapolis. It is stated that these trains will save a yearly aggregate of $192,200 in operating revenue and bring in an estimated additional revenue of $350,000. Purchase price of the complete trains is said to be $1,528,000. Two six-car diesel-electric trains, the Eagles, have been put into traffic by the Missouri Pacific between St. Louis, Kansas City, and Omaha. Each 265-ton train has accommodation for 230 passengers and is hauled by a 2,000 b.h.p. 132-ton Electro-Motive locomotive; the trains were built by the American Car & Foundry Company.

Büchi Pressure-Charging.—The German Reichspatentamt has completely rejected the suit of nullity brought by the French firm of Rateau against the German patent No. 568855 of Dr. Alfred J. Büchi, of Winterthur, Switzerland, covering exhaust-gas turbo pressure-charging. The Rateau firm was ordered to pay the costs of the case and those of Dr. Büchi.

Argentine Diesel Service.—The 12 Ganz twin-car diesel-mechanical trains of the Central Argentine Railway are now making an average aggregate monthly mileage of 100,000. Normally, two of the sets are in dock at any one time for light or heavy overhaul, so that the average monthly mileage per set in traffic is 10,000.

New Engine Type.—Ganz & Co., of Budapest, has extended its range of railway oil engines by a V type with 12 or 16 cylinders to give maxima of 600 b.h.p. and 800 b.h.p. at 1,250 r.p.m. In actual installations the engines will probably be set to give top outputs of 75 to 80 per cent. of the above figures. The cylinders are 6¾ in. by 9½ in. and the engine weight about 15 lb. per b.h.p. against the maximum output. The cylinder banks are set at an included angle of only 40 deg.

Trade Publications

Tandem News.—The issue of this journal for the first quarter of the year, in addition to dealing with various bearing alloys of the Eyre Smelting Co. Ltd., contains a short article on diesel engine bearings by Mr. P. H. Smith and a short note on Isaac Babbitt, who at an early stage developed light metal for bearing purposes.

National Bulletin.—The March issue of this Bulletin coming from the National Gas & Oil Engine Co. Ltd., of Ashton-under-Lyne, contains some extremely interesting results obtained with a pressure-charged stationary type of engine, with a normal output of 1,120 b.h.p.; indicator, entropy, and exhaust-pressure wave diagrams are included. The April issue is devoted to diesel power plants for tin dredgers.

Sulzer Technical Review.—The English edition of the third issue of 1939 has just reached us. It contains a long article on ignition lag in diesel engines which is an abstract of a thesis presented at the University of Cambridge by Mr. H. H. Wolfer. Issue No. 4 for the year 1939 contains a lengthy description of the 1,200 b.h.p. diesel-electric locmotives built last year for the Swiss Federal Railways and described in the issue of this Supplement for May 12, 1939.

Clayton Heater.—One of the most popular heaters for rail and road passenger transport vehicles is described in a brochure bearing the above title sent to us by the Clayton Dewandre Co. Ltd., of Lincoln. Making use of the engine cooling water, and having the admission of air to the car under a control quite independent of the heater, the Clayton-Dewandre heating unit comprises a hot-water radiator which incorporates a Clayton-Still tubular heat-radiating element and an electrically-driven air circulating fan under thermostatic control. This brochure describes the heater and also the installation and piping to and from the engine.

Diesel Railway Traction

The Zephyrs

SINCE the recent acquisition of five 4,000 b.h.p. diesel-electric locomotives, the Chicago, Burlington & Quincy Railroad, owner of the celebrated Zephyr trains, has had in traffic 15 diesel-hauled or diesel-propelled trains with an aggregate engine output (traction) of 35,240 b.h.p. which make a daily mileage of 11,034 at start-to-stop speeds up to well over 80 m.p.h., and give a daily average per locomotive of 735½ miles. The fastest run is by one of the 1,800 b.h.p. Twin Zephyrs, train No. 21, which is booked to leave East Dubuque at 11.42 and re-start from Prairie du Chien, 54·61 miles away, at 12.21 p.m. This corresponds to 83·9 m.p.h., but if half-a-minute be allowed for the stop at Prairie du Chien the start-to-stop speed is 85 m.p.h.; either method of reckoning gives the fastest run in the world. The present Twin Zephyr trains were originally seven-car (including the power car) sets, but in 1937 a further dinette-coach vehicle was added; the present tare weight is 340 tons and the traction b.h.p. 1,800. In a recent paper, Mr. E. F. Weber, Superintendent of Automotive Equipment of the Burlington Lines, mentions that the cost of locomotive maintenance and general repairs for the four 660 b.h.p. Zephyrs has averaged 4·49 cents a train mile since the Pioneer Zephyr was placed in traffic in 1934. For the two 3,000 b.h.p. Denver Zephyrs the corresponding cost has been 15·68 cents a mile since the introduction of the trains in November, 1936. Averaging 65 m.p.h. over the 1,036 miles between Chicago and Denver, the Denver Zephyrs consume an average of 3,771 U.S. gal. of fuel for the round trip of 2,072 miles, and of this 82·3 per cent. is for traction, giving a specific consumption of 0·55 m.p.g. (U.S.). Train heating accounts for 13·7 per cent. and auxiliaries for 4 per cent. of the fuel consumption.

Gas Railcars in Belgium

DELIVERY of 50 four-wheel diesel-mechanical railcars of Brossel manufacture to the Belgian National Railways began in September last, and in view of the immediate accentuation in the difficulties of fuel supply, it was decided that two or three of the vehicles still under construction should be equipped with producer-gas plant, work on the remaining cars being delayed until preliminary tests had been made with the remodelled cars. The trials proving satisfactory all the remaining cars except two were turned out with producer-gas motive power; the two cars just mentioned were fitted to run on compressed town gas. Until the German invasion of Belgium all these cars were running regularly in local service. The single-charge mileage of the compressed-gas cars has been about 112-115 miles, and the daily scheduled mileage appears to have been limited deliberately to this mileage because of the great time needed for recharging, although the storage pressure is only 2,150 lb. per sq. in. Indeed, one report says that these two cars operate only on alternate days, inspection and recharging occupying most of the free day. On the other hand, the producer-gas cars have been running averages up to 186 miles a day with little trouble and with no special care. The engine power, both at maximum speed and maximum torque, is said to be 15 per cent. less than that of the diesel in the earlier cars. Originally charcoal was used as fuel, but as the wood for this was imported endeavours were soon made to use anthracite fuels, and the latest information is that a mixture of 84 per cent. anthracite and 16 per cent. charcoal was being used. Although this mineral fuel does not seem to be of a very special type, the filtering arrangements have apparently been successful enough to keep the cars running at a respectable daily mileage, but cylinder wear figures are not known. The actual running cost of these cars is said to be 57 centimes per kilometre, of which 27 centimes represents the fuel cost; the diesel cars cost 75 centimes per kilometre and the two compressed-gas cars 85 centimes.

Fuel Injection and Combustion

TAKEN generally, there seems little prospect of any appreciable advance in the thermal efficiency of the high-speed oil engine as used in railway work, although, of course, a majority of existing designs could be improved to the figures of the best engines. The principal likely avenue of advance appears to be in the use of heavier and inferior grades of fuels by engines of all types, and the time will come, probably sooner than later, when engines will have to operate satisfactorily on grades of oil now considered quite unsuitable. Not inaptly, the heart of the modern high-speed oil engine has been said to be the injection system, and it is one of the most important factors in widening the practicable range of fuels. Its success is mainly in the hands of the designer and manufacturer, and some of the problems of injection and combustion with which the designer is faced are covered in an article by Mr. G. H. Paulin, in the April issue of the *English Electric Journal*. Referring to the English Electric H-type engine, a four-stroke model running at a top speed of 1,500 r.p.m. and installed *inter alia* in the Ceylon trains, Mr. Paulin says that at full load each pump ram and injection valve must deliver 0·0003 lb. (0·00945 cu. m.) of fuel 750 times a minute at a pressure of several thousand pounds a square inch ; the injection time is about 0·0022 sec. Injection of the fuel too early before top dead centre may mean that the fuel enters the cylinder before the compressed air charge reaches an adequate temperature, giving greater ignition lag and an increased rate of pressure rise, leading to combustion knock. Wave propagation in the fuel lines may lead to difficulties, and in the English Electric K-type engine—as used in the L.M.S.R. 350 b.h.p. shunting locomotives—has resulted in the fuel pump elements being located only a short distance from the injection valves, ensuring freedom from uncontrolled wave action. Apparently the speed of wave propagation is about 4,400 ft. a second, and in the K engine, where the fuel delivery line is 1·66 ft., the wave takes 0·00038 sec. to travel from the fuel pump to the nozzle. With the engine running at 600 r.p.m. and a full-load injection period of 20 deg. of crankshaft travel, the injection period is 0·0055 sec., so that the pressure wave has time to travel approximately seven times through the line in both directions during the injection period.

RAILCAR MAINTENANCE ON THE GREAT WESTERN RAILWAY

A description of the maker's maintenance arrangements over a vehicle mileage of four million

By C. F. CLEAVER, Director, Hardy Motors Division, A.E.C.

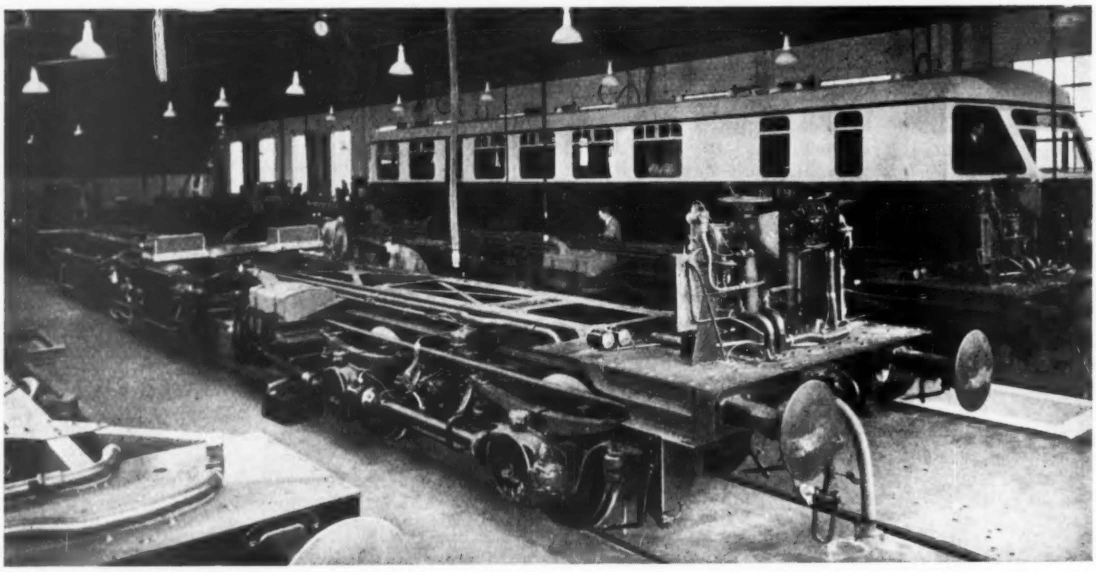


Fig. 1.—Railcar repair shop at the Southall works of the Associated Equipment Company

SINCE the Great Western Railway began running railcars about six years ago the maintenance has been undertaken on a mileage basis by the makers, the Associated Equipment Co. Ltd., of Southall. The firm's designers thus have been kept in close touch through their service men with the working of the cars, and the slightest defect, or possibility of improvement, has been brought to their notice. Otherwise many minor faults might have been remedied by the railway without the makers' attention being called to such details.

The service men are carefully selected for the job, and are able to bring forward useful suggestions from their own observation. The railway staff has been helpful with criticism and advice, and another result of this combination of operator and manufacturer has been the possibility of gauging the railway's requirements, and thus being able to produce machines to meet them.

Mileages and Service

This system of maintenance has now extended over about 4,000,000 miles of running. Where a single failure occurs, it is possibly regarded as accidental or just bad luck, but if this particular feature gives trouble a second time, a careful investigation is made, and the resulting alteration in design is applied to all cars as soon as possible, as well as being borne in mind when new designs are being considered.

Apart from the original car—No. 1—which up to April of this year had covered over 320,000 miles, 11 others have already run upwards of 200,000 miles each on services which vary between one car which, stopping at 14 stations daily at an average of 20·4 miles apart, shows a start-to-stop speed throughout the day of 49·3 m.p.h., and another with corresponding figures of 99 stops 2·2 miles apart and an average speed of 23·9 m.p.h. This low speed is partly accounted for by track restrictions. Another car with 167 stops at 1·5-mile intervals maintains a speed of 28·9 m.p.h. The complete stud of G.W.R. railcars has been described fully in past issues of this Supplement.

Maintenance has not been too easy, as the 18 cars are shedded at no fewer than 10 places spread well over the southern part of the G.W.R. system, and as immediate availability of service men is of the greatest importance, it has not been possible to allocate them very economically. Six outside men are employed and are stationed as follows:—

Birmingham ..	2 men. In charge of Tyseley (2 cars); Worcester (3); and also of the Cardiff car which changes over at Birmingham, with spare when required for examination, etc.
Bristol.. ..	2 men. For Bristol (3), and Weymouth (1), which also changes over as required.
Newport ..	1 man. Takes care of Newport (1), Pontypool Road (1), and Landore (1). Takes on emergency work on Cardiff car, and borrows help from Bristol when necessary.
Oxford.. ..	1 man. For Oxford (2), and Reading (1). Is assisted by factory in heavy repairs, and in monthly examinations.
Southall ..	These two cars are handled by the factory staff.

The figures in brackets indicate the number of cars per shed, and of these one each at Birmingham, Worcester, Bristol, and Newport, are spares. This number is necessary as that at Birmingham is held solely for the Cardiff service; and for continuity of employment, overhauls at the factory are so arranged that one car is always

there, with a slight overlap to allow for testing, while others may be withdrawn for body repairs or periodical painting.

Service Men

Service men's duties, which of necessity must nearly always be carried out at night, consist of: examination of cars with a view to preventing failures or uneconomical working, by adjusting, replacing or repairing units which may need it; immediate attention to cars which may fail or are reported as defective by the drivers; attending the railway's monthly examinations; and taking down and cleaning engine sumps, and seeing that the oil is changed; riding, when possible, on the cars and giving advice and instructions to the drivers; riding on cars after they have been returned to sheds after factory overhaul, in order to make minor final adjustments found necessary in actual service.

The lubrication of the cars, as well as the replenishment of fuel, oil, or water, is carried out by the railway, which has its own tickler cards prepared in collaboration with the maker. Service men have authority to ask the G.W.R. officials to withdraw or replace any car that they may consider is in need of adjustment or repair. Each week the service men send in to the Southall factory a report on each car in their area. These report forms are printed in such a way that the minimum of clerical work is required, and the returns are entered at the factory on forms with headings corresponding with those on the weekly ones. Each such record sheet covers the working of one separate car for one year, and serves as a check that all periodical operations are being carried out regularly. They also carry a complete record of mileages, failures, overhauls, and other useful details (Fig. 2).

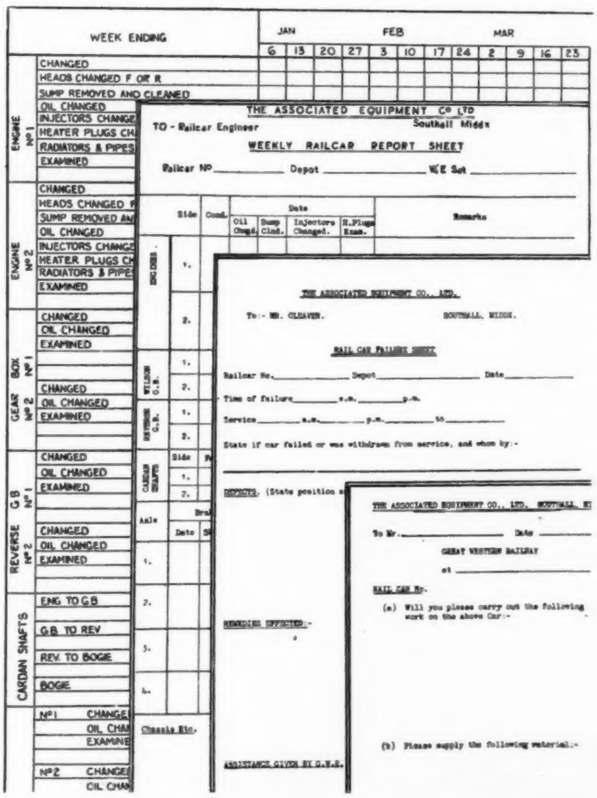


Fig. 2.—Weekly report sheet for one railcar

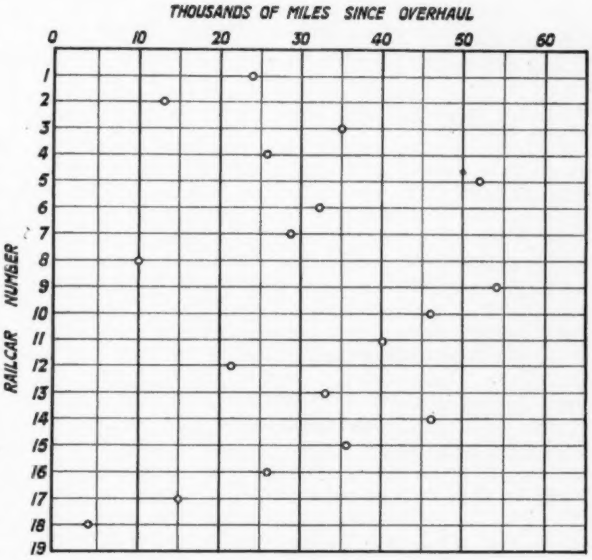


Fig. 3.—Chart showing mileage and incidence of next overhaul

When a failure occurs, full particulars as to car number, time, place, and nature, are immediately entered by the service man concerned on a printed form which is sent in to the factory, and at the same time a copy is handed to the railway officials who are thus kept fully informed as to the working of the cars. Where a service man is not immediately available, minor details such as brake adjustments, are attended to by the railway company's staff. This work is covered by an order from the service man in charge of cars at that particular shed, and the cost is chargeable to the manufacturer.

On an average each car is returned to the factory after approximately every **45,000** miles for a complete overhaul, but recently certain cars have been purposely allowed to run from **75,000** to **85,000** miles, and their condition then carefully examined. As a result of this, and the general state of cars when they arrive at the factory, it has been decided that the period between overhauls may safely be extended to **75,000** miles.

At these overhauls all major units are removed, and, according to their state, they are either reconditioned in the railcar shop, or are sent to the maker's service station, where they are stripped down, rebuilt with new parts where required, and after bench testing are sent back for replacement in the car. All other smaller units are carefully examined, and are repaired, adjusted or replaced, as necessary. Each car as it comes in for overhaul has the tyres inspected by a railway representative, and if tyre wear has reached a predetermined limit the car is lifted, the bogies withdrawn, and wheels and axles are sent to the G.W.R. Swindon works for attention.

When ready, the car is given two or three days' test on the Southall—Brentford branch, and it is returned for service only when the maker is satisfied as to its condition. Even so, the local service man then rides on the car for its first few days' running until it is properly bedded in. An average overhaul takes from **10** to **14** days, but when wheels and axles are sent away for turning or re-tyring, some delay may occur from either material or transport difficulties.

A chart, brought up to date every four weeks, is used, and by means of pins the mileage of every car since its last factory visit is clearly shown, and the time when its next overhaul is due may be gauged. As a car comes in, its pin is moved back to zero, until the next mileage return

is received (Fig. 3). A mileage return is sent in by the railway every four weeks, and this contains details of any failures, as well as of time spent on repairs at Southall and Swindon. The maintenance staff at the factory, apart from men in the general service station where major unit overhauls are undertaken, consists of a foreman, a clerk responsible for records, material requisitions, reports, etc., and 10 fitters, including a competent electrician.

Before dealing with a consideration of actual failures and the steps taken to avoid their repetition, some details extracted from the maker's records of the working of average cars may be given. For this purpose cars Nos. 1, 11 and 17 have been taken, as they are as far as possible always kept on the same services. Car No. 1 is the original single-engined one used for suburban work; the running of No. 11 is of a semi-fast nature; and No. 17 is the parcels car.

The figures in the last column of each table indicate the number of station stops (including terminal) per trip. For example, car No. 1 leaves Southall at 8.33 a.m. and after calling at 13 stations arrives at Didcot 10.01 a.m. It will be seen that where although 12 hr. are available each night for maintenance on car No. 1, and 14 hr. on No. 11, No. 17 is only in the shed from midnight until 3.30 a.m. The periods available for maintenance on these and other cars are shown graphically in Fig. 5, where the heavy black lines indicate the running times from midday to midday, and the gaps show all stops of 5 min. duration or more. The crossed open lines show light running to and from sheds.

The following is a summary of the working of these three cars for the 12 months ending August, 1939, out of which one week has been allowed for withdrawal of cars at holiday periods:—

	No. 1	No. 11	No. 17
Approx. annual schedule mileage ...	70,074	70,890	69,004
Approx. annual actual mileage ...	61,087	70,778	47,140
Availability per cent.	87·1	—*	68·5
Number of weeks for overhaul ...	5	4½	7
Number of weeks for body repairs	—	—	9

* Availability of No. 11 (stationed at Weymouth) cannot be estimated, due to extra workings and occasional interchange with Bristol car.

The comparatively low availability of No. 17 car is accounted for by the body overhauls. The mechanical records for this 12-month period are:

Car No. 1.—Overhauled 25.8.1938 to 15.9.1938 after 72,000 miles. Engine changed, gearbox and reverse box overhauled, brakes relined, and tyres turned. Failed 17.9.1938 with loose fuel pipe connection, causing shortage of fuel. 12,000 miles later reverse box was changed because of worn races, and self starter was replaced as the fields were shorting. Propeller shaft between axles removed for overhaul. On 16.1.1939 the car was withdrawn by driver who suspected strange noise; tappets were found to be slightly out of adjustment but car could have continued running. Oil leak developed at crankshaft filler block after 28,000 miles from overhaul, and engine was changed. Car failed 27.4.1939 with broken reverse control level. Taken out of service at 42,000 miles for factory overhaul (29.4.1939 to 13.5.1939). Engine overhauled in position, gearbox and reverse box changed, and two pairs of brake shoes relined. Total mileage at end of period, 310,805.

Car No. 11.—Engine changed at 5,000 miles due to noisy timing gears on one engine, and fuel pump changed on other engine. Car failed 23.12.1938 as two pistons were blowing, and car was withdrawn by driver. Two cylinder heads were changed at 24,000 and 25,000 miles respectively. Returned to factory for overhaul 14.2.1939 to 17.3.1939 after 40,000 miles. Engines and reverse boxes changed, but no attention necessary to gearboxes. New brake drums fitted and wheels re-tyred. Car failed 4.5.1939

Table I—Timetables of Cars Nos. 1, 11 and 17

—	Arr.	Dep.	Stops
Car No. 1—			
Southall	—	8·33	14
Didcot	10·01	11·07	10
Slough	12·11	12·15	5 (*sx*)
Reading	12·46	12·55	1 (*sx*)
Twyford	1·03	1·05	3 (*sx*)
Henley	1·16	1·34	3 (*sx*)
Twyford	1·46	2·24	1 (*sx*)
Reading	2·32	3·02	5 (*sx*)
Slough	3·33	3·55	1
Windsor	4·01	4·08	1
Slough	4·14	4·27	9 (*a*)
Oxford	6·34	6·44	16
Southall	8·28	—	—
Car No. 11—			
Weymouth	—	10·10	8 (*sx*)
Bristol	12·13	12·25	6 (*sx*)
Salisbury	1·45	2·10	15 (*sx b*)
Weymouth	5·32	6·05	3 (*sx*)
Yeovil	6·45	7·50	5 (*sx*)
Weymouth	8·32	—	—
Car No. 17—			
Southall	—	3·30	1
Kensington	3·50	4·50	2
Oxford	6·35	6·45	23 (*c d*)
Paddington	11·05	1·03	15 (*sx*)
Reading	2·42	3·56	15 (*sx c*)
Paddington	7·45	10·30	6 (*sx*)
Hayes	11·44	11·55	1 (*sx*)
Southall	12·00	—	—

(*a*) Stops at Reading for 57 min.; (*b*) Stops at Westbury for 70 min.; (*c*) Includes several stops of up to 60 min.; all stops for car No. 17 are 2 min. or more; (*d*) Terminates at Southall on Saturdays; Sunday running as on Saturdays; (*sx*) Saturdays excepted.

Fig. 4.—One of the double-bogie cars—No. 11—built in 1936, and used on the Weymouth-Bristol service

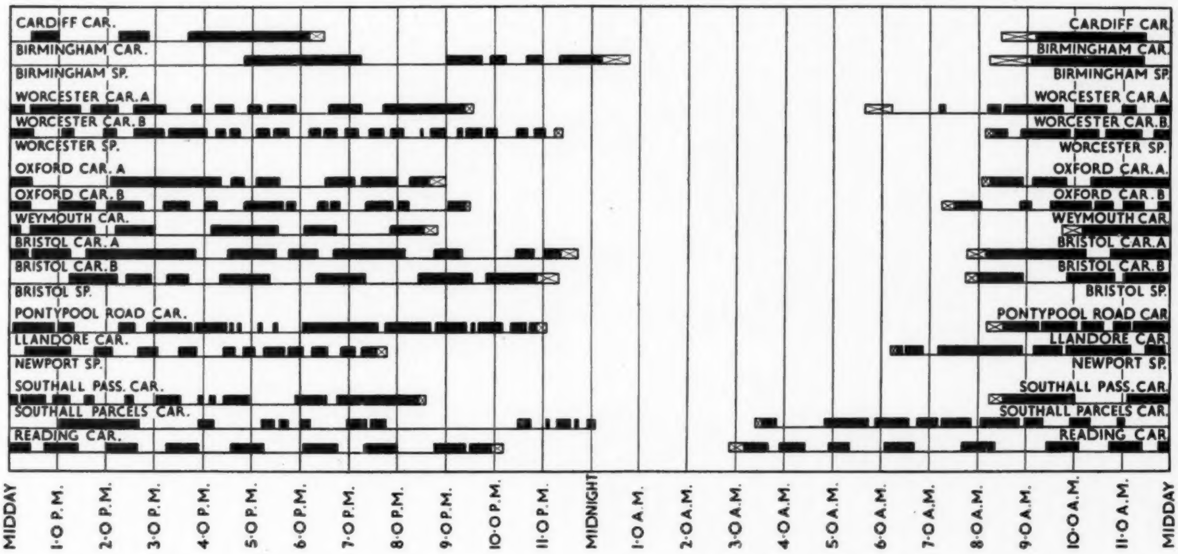


Fig. 5.—Chart of daily scheduled duties, showing time available for inspection and maintenance, G.W.R. diesel railcars

with broken gear-selector rod, and on 10.7.1939 with seized fuel pump coupling. After 68,000 miles one gearbox was changed owing to a tendency to stick in top gear. Total mileage at end of period, 218,463.

Car No. 17.—Withdrawn after 15,000 miles as one engine developed a slack main bearing, engine changed. Later a self-starter was changed as contact switch was burnt. On 28.11.1939 the car was withdrawn for three days, and two new direct-injection engines were fitted experimentally. A defective water pump was replaced after 23,000 miles. A fused self-starter contact caused a failure on 25.1.1939. Car was taken out of service 18.5.1939 to 20.6.1939 for examination of new engines, and as tyres needed attention complete chassis overhaul was made (56,000 miles since last one). Engines, gearboxes and reverse boxes were stripped down for examination but were not changed. Three new brake drums were fitted, three pairs of shoes relined, and tyres were turned. On completion car was sent to Swindon for body repairs and repainting, and resumed service 23.8.1939. Total mileage at end of period, 183,158.

Table II.—G.W.R. Railcar Failures 1937–8–9; expressed as percentages of total for three years

——	1937	1938	1939
	Per cent.	Per cent.	Per cent.
Engine bearings	5·44	1·64	0·91
Pistons	3·64	2·94	2·72
Heads	1·09	0·33	0·91
Timing gears	1·81	0·33	—
Water pump	0·73	—	—
Fan	0·73	0·33	0·45
Oil pump spindle	0·73	0·33	—
Starters	2·55	3·92	1·36
Batteries	1·81	—	0·45
Fuel system	0·73	4·24	2·72
Fluid flywheel	0·36	0·65	0·91
Gearbox	4·35	0·65	1·36
Reverse box	1·45	0·33	—
Gearbox and reverse controls	0·36	0·33	2·72
Solenoids, etc.	3·26	1·34	—
Axleboxes	1·81	1·64	0·45
Propeller shafts...	3·26	—	—
Bogies	0·36	0·98	—
Brakes	6·17	2·61	0·45
Miscellaneous	6·53	5·87	3·19
Human	5·44	0·33	—
	52·61	28·79	18·60

Approximate annual mileages :—

1937	... ...	875,000
1938	... ...	975,000
1939	... ...	700,000 (up to 9.12.39)

Figures are compensated and given on basis of equal annual mileages.

In Table II, an analysis is given of the failures reported by the G.W.R. in its monthly returns for the three years ending 9.12.1939. The figures for 1937 and 1939 have been proportionately increased to compensate for the greater mileage run during 1938, and the percentages are given for the total thus arrived at for the three years. The last heading—human—covers such failures as were due to fuel cocks being left only half open, radiators freezing up when anti-freeze had not been put in, etc., and possibly other failure may have been caused by oversight, but where any doubt exists, the failure is booked against the car. Over-caution on the part of drivers has sometimes resulted in withdrawal when actually this was not necessary, but such a fault is preferable to rashness. In dealing with the various causes of these failures, as set out in the table, details of other improvements, not actually found necessary by failures, have been included.

Engine

Bearings.—Failures from seized bearings, generally big-end, have been considerably reduced by fitting a larger oil delivery pipe which is directly connected to the bearing caps; the original pipes, of relatively small diameter, were found to close in at the " olive " connections after they had been taken down once or twice. Considerable improvement has been effected by changing the engine oil every 5,000 miles in order to prevent sludging. Soon after introducing railcars, it was found that aluminium crankcases caused bearing trouble through distortion, and cast iron was substituted; on continuous high-speed runs, oil coolers were found essential.

Pistons.—The lack of head between engine and radiator top tank, unavoidable where all units are kept below floor level, resulted in air being carried round in suspension in the cooling water, causing over-heating and piston seizures. This has been remedied, after various experiments, by providing a header tank where the water is passed through baffles before entering the radiator. The resultant slowing down of the water through these baffles allows such air to separate out. These tanks are housed under convenient seats. Experience has also shown that

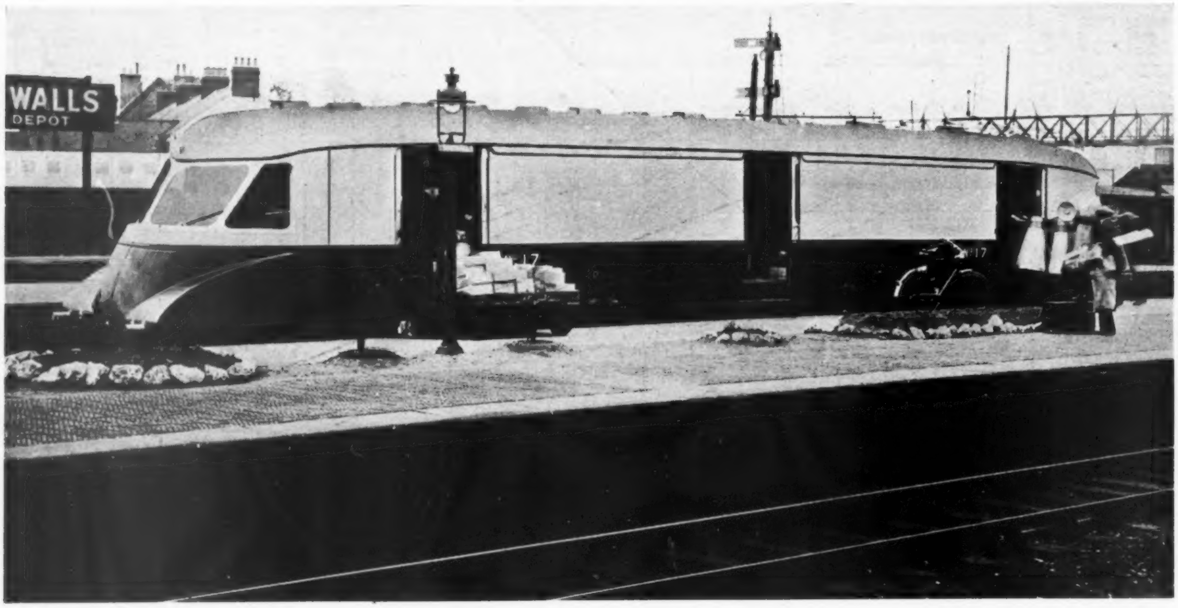


Fig. 6.—The parcels car, No. 17, which makes daily runs from a West London depot up the Thames Valley main line as far as Oxford

larger piston clearances are desirable on railcar engines compared with those in road vehicles.

Cylinder Heads.—Trouble has been caused through these becoming loose at the venturis, or through cracking. The design has been altered accordingly.

Timing Gears.—Sudden snatch, caused by inexperienced drivers, resulted in trouble from broken timing chains. Timing gears were substituted, but after about **80,000** miles' running an epidemic of stripped gears occurred. Wider gears and a more foolproof mounting were adopted, and the trouble was cured.

Water Pumps, Fans, and Oil Pumps.—A few cases of trouble have been met with due to broken spindles, but an improved design has been introduced.

Starters.—The chief source of trouble has been worn pinions, caused by the starters being engaged when engines were already running, but burnt solenoid switches have also caused trouble.

Batteries.—The chief trouble is due to batteries being allowed to run down. Loose connections are occasionally met with.

Fuel System.—The chief cause of trouble under this heading may have been human, where washers have not been properly replaced after cleaning, resulting in air locks. Some failures have been the result of dirt in the system and of defective fuel lifts and loose pipe unions.

Fluid Flywheel.—Lack of oil has been at the bottom of these failures, through filler plugs not having been replaced correctly. An improved plug is now used.

Gearbox.—Sticking in top gear has been cured by the use of a plate clutch in place of the cone type. Although the bands are self adjusting, such adjustment does not take place unless the bus-bar is pressed down and released sharply. To compensate for this the drivers are instructed to " pump up " the gears nightly by engaging and releasing each gear sharply four or five times. Failure to carry out this instruction regularly has resulted in a number of failures, which, however, cannot be booked as " human." Improvement has also been made by using a stronger automatic adjusting spring. Trouble is sometimes experienced with broken bands, broken spring buckets, and sticking selectors.

Reverse Boxes.—The only troubles booked against this unit have been worn or collapsed ball races.

Controls.—Gearbox and reverse box. Failures from broken ball joints have been eliminated by replacing with fork ends having spherical bushes. On one occasion a clutch servo cylinder was broken by something thrown up from the track. An epidemic of broken reverse control levers was experienced after the cars had been running for about **200,000** miles, and was found to be the result of fatigue caused by side pull and twist from non-alignment. The design has since been altered to prevent this. The high figure under this heading in **1939** was due to the failure of these levers.

Solenoids, etc.—These failures apply to car No. **18** which is fitted with distant control, and happened during its experimental period. Considerable trouble was experienced with the magnet valve return springs collapsing. On the advice of London Transport engineers these valves were reversed so that the solenoid did not rest on the springs, with excellent results. Valves which had been affected in this way had caused a loss of air pressure. The solenoids acting directly on the preselector struts also used to stick due to the vacuum cup effect of their stop plates (immersed in oil), until grooving was introduced.

Switch contacts have given a certain amount of trouble unless cleaned at frequent intervals, but on the latest design silver contacts are used and do not suffer from tarnishing when used with low voltage and amperage. Drop of voltage in the battery has been a source of trouble. This was discovered when a series of failures occurred where the solenoids would not operate against full air pressure. Investigation showed that these always happened on the last trip on a Saturday night when an extra trip was run and the lights were left on for excessive periods. The air pressure setting was found to be higher than necessary, and by lowering this the trouble was overcome. The specification of magnet valves on later cars has been set out to cover this loss of voltage.

Axleboxes.—A number of failures was caused by collapsed bearings, and it was found that insufficient clearance had been allowed for pressing on to the axles and into the boxes. This has been corrected. On worm-driven axles a differential was used to compensate for

differences between wheel diameters, but it has been found that tyres can be turned to such accurate limits that this is unnecessary, and they are not used on later designs. As rail wheels have not the same cushioning effect that rubber tyres have, shock has caused fracture of some of the driving shafts and they have had to be replaced by a stronger design.

In the early days trouble was given by leaky glands. The bellows type of gland is extremely efficient, but if it fails it does so suddenly. A secondary packing has therefore been fitted so that if the bellows fails the resulting leakage will be slow. Although the worm drive has been superseded by bevels, this is solely so that the reversing gear may be incorporated in the axlebox, and thus to cut out an additional unit. In service, worms and wheels have been found capable of giving a life of upwards of 250,000 miles.

Propellor Shafts.—After the first seven cars, needle roller shafts were introduced instead of the plain bearing type. Although they had been found most satisfactory for road work, they were not suited for railcars and had to be replaced by the original design. The reason was that their plunging action did not promote lubrication and seizures were experienced on the shaft from gearbox to axlebox, where considerable longitudinal movement takes place.

Brakes and Bogies

Brakes.—Cast-iron drums were used on the first car and were entirely satisfactory, but when high-speed cars were introduced cracking ensued. Cast steel was tried, but although not so prone to cracking the drums scored. Considerable improvement was effected by the use of carbon-steel forgings. Brake lining life remains a mystery. A set of linings on one car may average only 6,400 miles, yet another car may give 33,100 miles; on car No. 18 (the relatively slow-speed trailer-hauling vehicle) the first set was renewed at 87,000 miles and the second set is still in use. Generally speaking, brake liner life seems to be a function of maximum speed rather than of the number of stops a car may make, but the gradients on the route over which the car usually works have a considerable effect.

The use of drum brakes was dictated to a considerable extent by the amount of vacuum available, and to the fact that due to small clearances, and thus small movements, little vacuum was necessary. Although the efficiency has been good, maintenance has been heavy. On later cars trailer haulage has been introduced, and equipment to apply the trailer brakes has been required. Therefore standard clasp brakes have been adopted.

Bogies.—Early bogies were of light welded construction and gave trouble from cracking; they have been rebuilt with heavier sections. Bad riding was cured when it was found that springs had been adjusted to give equal wheel weights, without allowing for differences in unsprung weights caused by driving axleboxes and brake gear. Hunting at high speed (particularly prevalent on the first three Birmingham—Cardiff cars) has been largely eliminated by fitting hydraulic shock absorbers to the spring bolsters. Fatigue resulted in a few failures, where side bearing springs broke after about 200,000 miles' running; swing links showed signs of wear at about the same period.

Miscellaneous.—These failures consist of such things as burnt-out dynamos and indicator lamps, and where the driver withdrew the car as the oil pressure was not registering, only because the lamp had burnt out. A starter button came loose on one occasion and caused the starter to engage while the engine was running. Collapsed air cleaners have occasionally shut off the air to the engine; steps have been taken to prevent this happening again. Oil pressure switches caused trouble until a satisfactory one was found. Heater plugs have burnt out, and rattling control rods have made drivers suspicious.

Weight

The question of weight must always come into the design of railcars, but reliability must not be sacrificed for this. The maker's experience of these cars has been that what may be quite satisfactory in road practice may not suit railway working. Aluminium crankcases are an example of this, and trouble resulted from too light a construction of the bogies, although theoretically the design might have been considered sound. For trailer working a reasonably heavy frame is necessary to withstand shocks, and in case of a derailment the underframe must be strong enough to stand lifting from one end. Drum brakes effect a saving in weight of about 30 cwt. but are heavy in maintenance.

The weight of car No. 1 as originally built was 20 tons, but this was increased when emergency buffers and a.t.c.

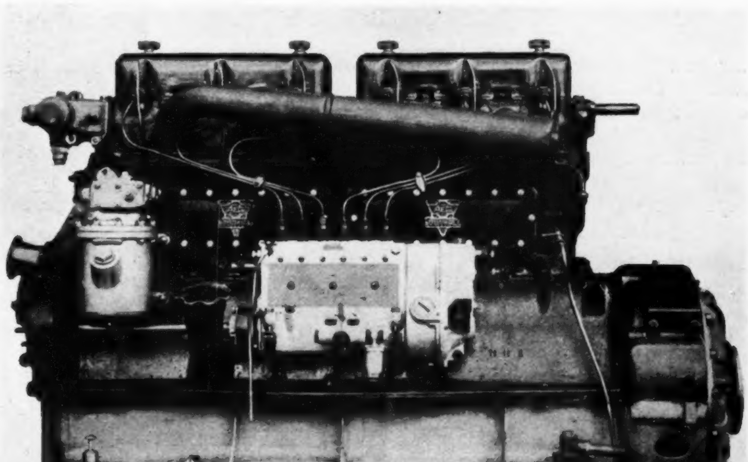


Fig. 7.—The new A.E.C. direct-injection engine giving 105 *b.h.p. at* 1,650 *r.p.m., which has replaced the original* 10-*litre engine which gave a maximum output of* 130 *b.h.p. at* 2,000 *to* 2,200 *r.p.m.*

Table III.—Weights of Constituents, G.W.R. Railcars

	No. off	Tons	Cwt.	Qr.	Lb.
Underframes, bogies, brake gear, buffers, drawgear, and A.T.C. equipment	1	20	0	0	0
Engine with suspension brackets	2	1	16	2	18
Throttle motor	1			1	0
Fuel tank with straps	3		4	0	8
Header tank	2		1	2	10
Silencers and exhaust pipes	2 sets		1	1	13
Radiator	2		7	2	16
Radiator cowl...	2		2	1	8
Countershaft bracket and fan assembly	4		2	1	16
Countershaft	2			2	14
Dynamo with pulley and bracket	2		2	2	12
Exhauster with pulley and bracket...	4		2	0	24
Oil separators	2			3	24
Vacuum filter comp.	1			1	3
Cardan shafts	4 prs.		'	2	0
Gearbox, main and aux., with brackets	2		14	1	0
Preselector motor	2			2	20
Driving axlebox, with bearings and torque arm ...	4		see note		
Double pinion assembly	2		1	1	24
Single pinion assembly	4		2	0	16
Control table	2		2	3	14
Instrument panels, complete	2		1	3	4
Driver's brake valve	2			1	9
Battery	1		10	1	18
Self-starter solenoids	1			1	1
Junction boxes	3		1	0	18
Control boxes	2			1	9
Magnet-valve assemblies	2		1	0	7
Jumper receptacle	4			2	24
Conduit	1 set		1	1	18
Cable ... ... approx.	—		2	1	0
Main horns and brackets	2 prs.				27
Stand-by horns and brackets	2 prs.				25
Stand-by horn motor compressors	4			1	12
Air reservoirs	1 pr.		1	0	8
Pipes, rods, etc.	—		14	2	0
Chassis complete	...	26	8	0	0

Driving axleboxes, complete with bearings, sleeves and torque arms, weight 3 cwt. 19 lb. each, but this weight is included in the unde frame and bogie total.

Table IV.—G.W.R. Diesel Railcar Mileage

Car No.	Placed in Service	Total Mileage to 30.3.40
1	5.2.34	321,361
2	9.7.34	204,381
3	17.7.34	220,476
4	22.9.34	231,584
5	22.7.35	226,362
6	30.8.35	232,405
7	8.7.35	252,765
8	5.3.36	182,631
9	3.2.36	244,390
10	17.2.36	243,309
11	17.2.36	228,226
12	11.2.36	240,004
13	16.3.36	149,412
14	23.3.36	191,856
15	6.4.36	208,742
16	17.4.36	164,301
17	27.4.36	205,946
18	4.4.37	144,746
	Total ...	3,892,587

gear were added, and at a later date when the bogies were rebuilt. The next six cars varied from 25 tons 6 cwt. to 26 tons 4 cwt. according to the body design, but the bogies were later replaced by others of a heavier design. These cars had twin engines, whereas No. 1 had only one. The bogies on the next ten cars were of the revised design, deeper section underframes being introduced; these were reinforced at the ends to allow for lifting, and the car weight went up to 28 tons 16 cwt.

When No. 18 car was designed, the bogie wheelbase was increased from 7 ft. to 8 ft. 6 in., longer side bearing springs were introduced, and the whole construction stiffened up to suit. Standard buffers and drawgear were necessary, and exhaust-heated boilers for trailer-working were added. The tare weight was 33 tons 12 cwt. The 20 new cars are generally similar to No. 18, except that oil-fired boilers are used instead of the exhaust type, and clasp brakes are embodied instead of the drum type, and the finished weight of the cars is 35 tons 13 cwt. Individual unit weights on the latest cars are given in Fig. 12.

At the beginning of the war all but five of the existing cars were withdrawn temporarily, as their passage, with a limited number of passengers, could not be allowed to interfere with the large volume of goods traffic on the main lines. Outside service men were nearly all withdrawn, and with their help, and that of a few additional men, the maintenance staff at the factory assembled the new car chassis at the rate of one every 10 days. In this way these service men are becoming fully acquainted with the cars of which they will later be in charge.

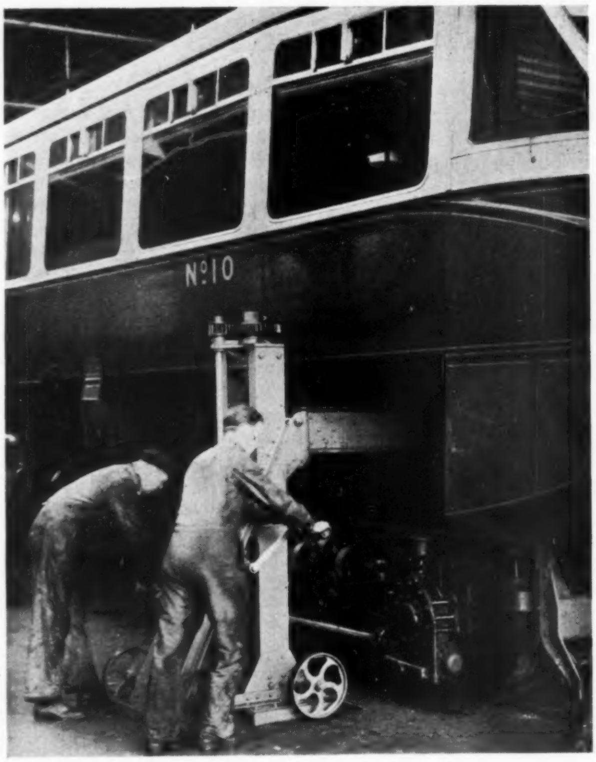


Fig. 8 (above).—Lifting a railcar for heavy repairs at the Southall works

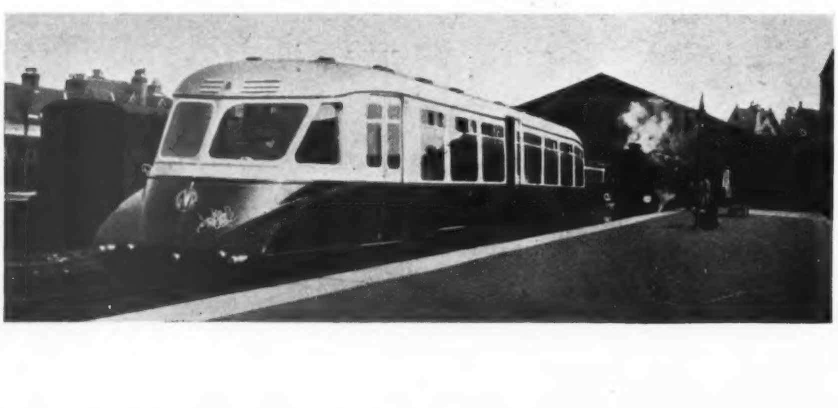
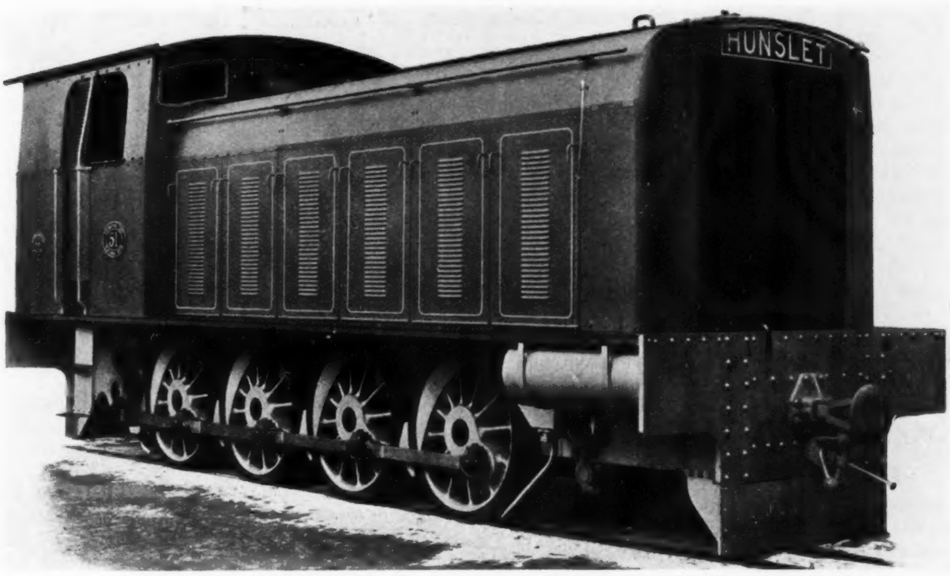


Fig. 9 (left).—One of the double-engined A.E.C. railcars in Weymouth station

ENGLISH-BUILT DIESEL FOR THE WEST INDIES

Locomotive to operate in atmosphere of high temperature and high humidity



Hunslet locomotive for the Trinidad Railways

AMONG the exports of railway material from this country during the past few weeks is included an 0-8-0 standard-gauge diesel-mechanical locomotive built by the Hunslet Engine Co. Ltd. for the Trinidad Railways, which operate a system of 150 miles, with headquarters at Port of Spain. This locomotive was designed and constructed with the close co-operation of the Crown Agents for the Colonies and the Trinidad Railways' Chief Mechanical Engineer, Mr. F. B. Carmichael.

Mechanical Portion

In its mechanical design the locomotive is along normal Hunslet lines, built up on heavy plate frames well braced together, and with the transmission driving a jackshaft supported in the frames at the rear end. The 46-in. wheels have cast steel centres and are spread over a base of 12 ft. 9 in. The axleboxes and guides are also of cast steel, and have bronze-faced liners. The single-cab with duplicate controls, is at the back end, and in front of it is a large bonnet housing the main engine and auxiliaries. The total working order weight of 35 tons is fairly equally distributed over the four axles, and the maximum axle load is 8·8 tons. All wheels are braked on the Westinghouse compressed air system, with cylinders applying the blocks through compensated rigging. Air is supplied at a pressure of 100 lb. per sq. in. by a two-cylinder Broomwade compressor driven from the main engine by Thrapston Vulco endless V belts.

Power is provided by a Paxman-Ricardo six-cylinder engine set to give a maximum of 277 b.h.p. at a speed of 1,000 r.p.m. It incorporates the usual Paxman features of a deep crankcase with separate frames supporting the cylinder block, and cast iron wet-type liners surmounted by interchangeable cylinder heads. There is a pressure-lubrication system operated by duplicate gear-type pumps supplying oil to all the engine bearings; an Autoklean self-clearing filter is fitted in the oil-pressure system, and special attention has been given also to the air and fuel filtering. The cooling water radiator is mounted on the front end of the bonnet, and comprises 12 Serck detachable and interchangeable elements carried by a massive steel frame; certain sections are used to cool the lubricating oil. The starting of the main engine is effected by a Ford V8 petrol engine, itself started electrically, which has a maximum output of 90 b.h.p. at 4,000 r.p.m. This engine has push-button control from the driver's cab, and operates through a Bendix gear on to a toothed ring on the engine flywheel.

Transmission and Controls

The four-speed transmission comprises a Vulcan-Sinclair fluid coupling, a Hunslet auxiliary gear-change clutch, and a Hunslet constant-mesh gearbox giving track speeds of 5½, 8½, 12¼ and 18½ m.p.h. at top engine revs. The tractive efforts on the four gear steps are respectively 16,300, 10,500, 7,200, and 4,750 lb.

The control is of the usual Hunslet type with the maker's patent preselective gearchange. A single handwheel not only speeds up and decelerates the engine but also controls the gears, the actions taking place through a series of cam-operated pneumatic valves which deliver air at a pressure of 50 lb. per sq. in. to the small cylinders which control the gears, clutch and clutch-shaft brakes in their correct sequence of operation. The gearbox itself is of welded plate construction, split on each shaft line to facilitate inspection and dismantling. The right-angle drive comprises spiral bevels, and the spur gears also have helical teeth. Ball and roller bearings are used throughout the gearbox.

DIESEL LOCOMOTIVE WORKING ON THE SANTA FE

A summary of the working of 14 main-line units with outputs of 1,800 to 4,000 b.h.p., as given by Mr. H. V. Gill, Supervisor of Diesel Locomotives, A.T. & S.F. Railroad, in a paper read before the Society of Automotive Engineers

THE first main-line locomotive on the Atchison, Topeka & Santa Fe Railroad was put into traffic in November, 1935, about eight months after the first 600 b.h.p. diesel-electric switching locomotive of modern design had been introduced. Since that time 40 additional switchers and 13 high-speed main-line locomotives have been purchased. All the main-line units are powered by two General Motors two-stroke engines of 900 to 1,000 b.h.p., and some of them are working in pairs, giving an aggregate locomotive output of 3,600 to 4,000 b.h.p. The maximum safe speed is 117 m.p.h. when used with a 25 : 52 traction motor gear ratio. Up to November 1, 1939, the 14 main-line sets had made an aggregate mileage of 5,625,523, and the availability based on assigned mileage was 95·3 per cent.

Electric Transmission

At the present time electric transmission is one of the limiting factors as far as continuous operation on heavy grades is concerned. This is due to the necessity for dissipating heat from the traction motors and generators. For example, one of the 4,000 b.h.p. diesel-electric locomotives has a starting tractive effort of 103,300 lb. and 43,000 lb. at 30 m.p.h., but is limited to 26,400 lb. continuously at 40 m.p.h. Greater tractive efforts than this may be developed for short periods provided that the temperature limits of the transmission are not exceeded. These 4,000 b.h.p. sets can handle trains of 765 short tons weight up 1·8 per cent. grades on the fast schedules between Chicago and Los Angeles. In selecting or assigning diesel-electric locomotives, the thermal capacity of the electric transmission must be carefully considered to make sure that it is sufficient for the duty cycle. Traction motors within the last five years have increased in capacity from 240 to 500 h.p. and it is expected that further increases will be made in the thermal capacity and the mechanical strength to meet more severe duty cycles.

Table I.—Operating Cost of 3,600 h.p. Diesel-Electric Locomotives in High-Speed Passenger Service—Year 1938

	Cost per loco. mile
Fuel	\$0·0469
Loco. repairs, labour and material	0·1063
Lubrication	0·0151
Supplies	0·0028
Water	—
Total cost per mile	\$0·1711

Maintenance and Repairs

At Chicago the Santa Fe has built a shop specially designed for handling diesel locomotive repairs. It is 282 ft. long by 111 ft. wide and is equipped with cranes, hoists, drop tables, and machine tools. With these new facilities it is expected that repairs will be carried out with much greater expedition, resulting in greater service availability and a reduction in maintenance costs. In addition to the I.C.C. requirements, special maintenance and inspection schedule forms have been found desirable. Those for the switching locomotives are made up on a monthly basis but those relating to main-line locomotives are on a mileage basis. A copy of the second type of chart is carried on each main-line locomotive unit so that a record of the maintenance and inspection is always available to the running and repair forces over the whole system. A diesel maintenance man always rides on the main-line locomotives while they are in service. These men are organised on a system basis and make a complete log report of each trip, reporting to maintenance points all the repairs and inspections required and inspecting the locomotives sufficiently in advance of departure time to ensure that the necessary repairs have been properly made.

Approximately 63 per cent. of the repair charges of the diesel locomotives are for materials. As these materials are expensive and changes in design—particularly during the first few years—have been frequent, it was found desirable to set up a special system to govern the supply of spare parts on hand and the handling of worn or defective

Table II.—Principal Characteristics of Diesel-Electric Locomotives now in service on the Atchison, Topeka & Santa Fe Railroad

No. of locomotives	Manufacturer	Horse-power and class of service	Number of diesel engines per locomotive	Weight of locomotive	Maximum speed	Starting tractive effort	Electrical equipment
				lb.	m.p.h.	lb.	
4	EMC	600 h.p. switch	1	205,780	40	51,445	GE
1	BLW	660 h.p. switch	1	213,840	45	53,460	AC
3	ALCO	600 h.p. switch	1	196,240	40	49,060	1-GE 2-West
3	EMC	900 h.p. switch	2	257,340	40	64,335	West
12	ALCO	1,000 h.p. switch	1	227,900	60	57,000	GE
5	BLW	1,000 h.p. switch	1	244,970	60	62,000	West
13	EMC	1,000 h.p. switch	1	249,200	60	62,325	EMC
12 units	EMC	Road pass. 1,800 h.p.	2	290,500	117	50,750	GE
2 units	EMC	Road pass. 2,000 h.p.	2	306,900	117	51,640	EMC

EMC—Electro-Motive Corporation
BLW—Baldwin Locomotive Works
ALCO—American Locomotive Company
GE—General Electric Co.
AC—Allis Chalmers Mfg. Co.
West—Westinghouse El. & Mfg. Co.

materials over the whole Santa Fe system. All requisitions for new materials and disposition of worn and defective parts are handled through a central office. A specially trained man has been selected to follow this disposition of materials and he also keeps mileage records of locomotive performance and records of service obtained from cylinder heads, cylinder liners, pistons, traction motors, axles, wheels, and other parts that are subject to frequent inspection or renewal.

Engine Maintenance

All the existing main-line locomotives are powered by the General Motors two-stroke engine. As these locomotives are operated under a load factor of about 60 per cent. more trouble is experienced with the diesel engines than is found in shunting service, where the load factor is only about 15 per cent. In fact on the main-line sets the diesel engine maintenance and repair expenses comprise about 56 per cent. of the total locomotive repair costs. The use of good air filters and oil filters has increased the lubricating oil drain period from 5,000 to 100,000 miles of service. Cylinder liners, which originally wore anything from 0·05 in. to 0·06 in. in about 60,000 miles, are now removed when they have worn 0·02 in., but this, with improved design and operation, represents 325,000 miles of running. After withdrawal these liners are reconditioned for further use. The cylinder heads are repaired and reconditioned by welding after every 100,000 miles. The piston design has been improved considerably and at the present time the drop-forged aluminium type, with a greatly increased ring land width, is giving the most dependable service. Piston assemblies are removed for inspection every 100,000 miles. The service mileage received from pistons removed from main-line sets has averaged 220,000 miles, but this figure will be increased as the latest type of piston replaces the older design. Allison metal is being used for the pressure side of the crankshaft bearings and Satco metal for the non-pressure half. The capacity of lubricating oil pumps has been increased. Cooling air for the engine radiator is now carried through ducts, to eliminate dirt from this source getting into the engine rooms. All these improvements have made it possible to run the diesel engine for 100,000 miles in main-line service before it is dismantled for inspection.

Crankshaft Grinder

Engine crankshaft grinding machines designed by Mr. J. P. Morris, General Mechanical Assistant of the Santa Fe, have been built in the railroad shops and are now installed at one or two important points where the work of renewing crankshafts is done. They will grind the crank throws of either the V-type two-stroke engine or of the vertical four-stroke engines used for the switching locomotives. With the results given by these machines it is expected that crankshafts will have a life equivalent to 1½ million miles of main-line service before they have to be withdrawn for scrapping.

The wheels have also been greatly improved and the present service life is about 250,000 miles, with about 84,000 miles between tyre re-turning. Originally the six-wheel trucks were arranged with the traction motors on the first and third axles, but more recently experiments have been made with motors on the second and third axles, the front pair of wheels being used entirely to guide the locomotive.

One of the latest Santa Fe diesel activities has been trial running with a 5,400 b.h.p. (traction) diesel-electric locomotive in heavy freight service. This locomotive, built by the Electro-Motive Corporation and powered by four General Motors 1,350 b.h.p. engines, has been tried on other American lines also.

FUEL COMBUSTION PHENOMENA

Abstract of a paper read last year before the Society of Automotive Engineers by Messrs. Robertson, Rose and Wilson

EXTENSIVE tests have shown that in medium-speed and high-speed diesel engines fuels with a high cetane number start to burn earlier and continue to burn longer during the expansion stroke than others with low ignition values. There is very little change in ignition lag between no load and full load, and small differences measured could be accounted for by variation in the temperature of the cylinder walls, high cooling water temperatures giving a slight reduction in the ignition delay period.

Observations on a Fairbanks-Morse four-stroke engine equipped with a spherical air cell and running at 1,245 r.p.m. showed that the combustion period varied from 0·007 to 0·016 sec. When using fuels of 50/60 cetane value the ignition lag varied from 0·003 sec. with an injection angle of 36-37 deg. before TDC to 0·001 sec. at an angle of 10 deg. before TDC. The time for complete fuel injection averaged 0·003 sec. at three-quarter load.

Combustion Duration

If combustion in this Fairbanks-Morse engine was to begin 8 deg. before TDC and continue for 0·0165 sec. (equivalent to 123 deg. of crank travel) the burning would be in progress right up to the point at which the exhaust valve is timed to open, *viz.*, 115 deg. after TDC. Tests with a 56 cetane fuel gave combustion duration periods of 0·012 sec. with injection beginning 12 deg. before TDC (the normal for this engine) to 0·0162 sec. when injection began 21 deg. before TDC. A 47 cetane fuel gave corresponding periods of 0·007 and 0·010 sec. For all fuels the longest duration of combustion seemed to be with injection beginning between 18 and 25 deg. before TDC; on either side of this range the period decreased.

High cetane fuels showed a greater tendency to after-burning than fuels with a low ignition number. With fuel injection beginning at or near the 12 deg. before TDC which was normal for the Fairbanks-Morse engine, the higher the cetane number the more quietly did the engine operate. As the ignition lag was reduced from 0·003 to 0·001 sec. there was a gradual transition from rough to smooth running. High cetane fuels burned longer because the slow-burning nature of the combustible in the engine during the expansion period caused more after-burning, but with low cetane fuel the flame could be extinguished before combustion was completed.

Consumption and Ignition Quality

At full engine load a 60 cetane fuel injected 20 deg. before TDC had a combustion period of 0·01675 sec. as against 0·0143 sec. at three-quarter load, and 0·0175 sec. at full load with injection beginning 12 deg. before TDC compared with 0·01025 sec. at three-quarter load. Fuel consumption appeared to be improved by using a high cetane fuel for full or fractional loads but not for overloads, as with much fuel being injected the amount of after-burning seemed to have a bad effect on fuel economy.

A short combustion period might mean fast burning or incomplete burning. If the flame went out before combustion was complete, white smoke appeared in the exhaust. It was apparent that for maximum thermal efficiency a high cetane fuel should start to burn earlier in the engine cycle than a fuel of low cetane value, and probably the longer ignition lag of the low cetane fuel was offset by the higher rate of the initial burning.

FRENCH 500 B.H.P. RAILCAR

The Renault single-engined ADP type has been used for high-speed solo, trailer-hauling, and steep-grade working on three of the five regions of the French National Railways

IN 1935 a single-unit non-trailer-hauling railcar powered by one 500 b.h.p. oil engine was completed at the Billancourt works of the S.A. des Usines Renault, and was tried out on one or two of the then six big French lines before being set to work on the old Etat system near La Rochelle. One of the feats of this first car was a run from Paris to Strasbourg *via* Nancy and back *via* Mulhouse and Belfort, the distance of 689 miles being covered in a net running time of 482 min. and in a total time of 515 min., as described in the issue of this Supplement for January 24, 1936.

Since that time over a dozen railcars to the same general design have been built and are working a variety of services on the lines of the French National Railways. Compared with the original car, the latest vehicles are arranged for trailer haulage, and standard buffers and drawgear are fitted; certain other modifications have also been made to details of the chassis, bogies, engine and transmission, and provision has been made for multiple-unit operation. In many respects these single-engined cars may be considered as alternatives to the standard 500 and 600 b.h.p. cars with two 250 b.h.p. C.L.M. two-stroke or 300 b.h.p. Renault four-stroke engines. Some of them are operating over the steeply-graded lines in the Aurillac district, and they can be used to haul either special railcar trailers or standard steel coaches.

General Particulars

Accommodation for 64 seated and nominally 20 standing passengers is provided in addition to space for approximately $1\frac{1}{2}$ tons of luggage or parcels. In certain cars only first and second class seats were provided but now all these cars carry second and third or only third class passengers. The tare weight is 40·8 *tonnes* of which 25·4 *tonnes* is on the wheels of the driving bogie. Fully laden, the weight of the car is about 49 *tonnes*, of which 28 to 29 *tonnes* rests on the driving bogie. Heating of the latest cars is effected by an oil-burning hot-water boiler of the Miclausse type, but the equipment is so arranged that preheating of the car can be carried out by steam through standard connections. For both heating and preheating, connections are provided for trailers, and the complete heating apparatus on the car weighs about 1·35 *tonnes*. Ventilating air is drawn in through a duct on the roof at each end, depending on the direction in which the car is travelling.

The body and underframe of the car are built up by welding as a single unit of high-tensile nickel-chrome steel in the usual Renault fashion, in which the side members form the main girders. All wheels are braked by electro-pneumatic means, and the sand is similarly supplied. The air brake working alone with sand applied to the rails can stop the car on the level in 400 m. (438 yd.) from a speed of 110 km.p.h. (68·3 m.p.h.), but the emergency brake can stop the car in 410 m. (450 yd.) on a 1 in 100 down grade from a speed of 122 km.p.h. (76 m.p.h.). The passengers' emergency brake is able to stop the car in 430 m. (470 yd.) down a 1 in 200 grade from a speed of 105 km.p.h. (65 m.p.h.). A hand brake is fitted in each driving cabin.

As was shown by the Paris—Strasbourg—Belfort—Paris trial mentioned earlier, these cars are capable of a speed in excess of 100 m.p.h. under suitable conditions, but normally a top rate of 130 km.p.h. (81 m.p.h.) is all that is attained in service, and such a speed can be maintained on the level with the car working solo. When hauling a standard steel coach weighing 48 *tonnes* these cars can attain speeds up to 125 km.p.h. (78 m.p.h.) along the level. When hauling such a trailer uphill the following speeds have been noted: up 1 in 100, 54 km.p.h. ($33\frac{1}{2}$ m.p.h.) in third gear; up 1 in 66, 51 km.p.h. (31·7 m.p.h.) in second gear; up 1 in 50, 51 km.p.h. (31·7 m.p.h.) in second gear; and up 1 in 40, 30 km.p.h. (18·6 m.p.h.) in first gear. Working solo, the corresponding recordings were 109 km.p.h. (67·7 m.p.h.) in fourth; 90 km.p.h. (56 m.p.h.) in fourth; 76 km.p.h. (47·2 m.p.h.) in third; and 51 km.p.h. (31·7 m.p.h.) in second.

Engine and Transmission

Power and transmission equipment are along Renault standard lines, with the engine carried on the underframe above the driving bogie and the drive taken to the wheels below through a friction clutch, four-speed gearbox, and vertical, inclined, and horizontal cardan shafts and flexible couplings to both axles of the driving bogie. With the engine running at its top speed of 1,500 r.p.m., the gearbox gives track speeds of 29·5, 50·0, 89·6, and 125·5 km.p.h. (18·4, 31·2, 55·7, and 78 m.p.h.). The engine itself has 16 cylinders arranged in V fashion, and having a bore of 156 mm. and a mean stroke of 184 mm. (6·15 in. by 7·25 in.). The cooling water radiator is carried on the roof above the engine room and is itself cooled by natural draught. Each bank of cylinders has its own exhaust system, leading up through the roof behind the radiator bank.

Auxiliary equipment carried on the car includes two 1·8-kW dynamos and a 318-amp.-hr. 24-volt Tudor battery, which feeds the two 12-h.p. electric starting motors attached to the engine. The fuel tank has a capacity of 700 litres (154 gal.) and fuel is fed from it to the single 16-ram injection pump by a Siki pump. Five fire extinguishers are carried, one in each of the driving positions and three in the passenger saloons. A double-note warning system with four horns—known in England as the Desilux—is incorporated.

AMERICAN NEWS.—The Terminal Railroad Association of St. Louis is purchasing 10 diesel-electric shunting locomotives at a cost of $700,000, and the C.R.I. & P. is purchasing one 1,000 b.h.p. Alco diesel switcher.

AUSTRALIAN RAILCARS.—According to a recent report, the New South Wales Railways have in traffic 36 petrol railcars of 100 to 150 b.h.p., four petrol-hydraulic railcars of 260 b.h.p., and five 720 b.h.p. diesel-hydraulic power vans which operate with special trailers.

INDIAN RAILCAR SERVICE.—The double-bogie Drewry diesel cars built for the Nizam's State Railway (see issue of this Supplement for July 7, 1939) have been put into traffic between Bidar and Secunderabad, a distance of about 120 miles.

FUEL INJECTION AND COMBUSTION.—The April, 1940, issue of the *English Electric Journal* contains a long and valuable article on fuel injection and combustion in compression ignition engines, written by Mr. G. H. Paulin, Chief Engineer, Internal Combustion Department.

G
A

P

REGISTERED AT THE G.P.O. AS A NEWSPAPER

GOVERNMENT CONTROL OF RAILWAYS, p. 883 PRODUCER-GAS OPERATION, p. 894
AIR RAID SHELTERS IN DISUSED LONDON TUBE TUNNELS, p. 904

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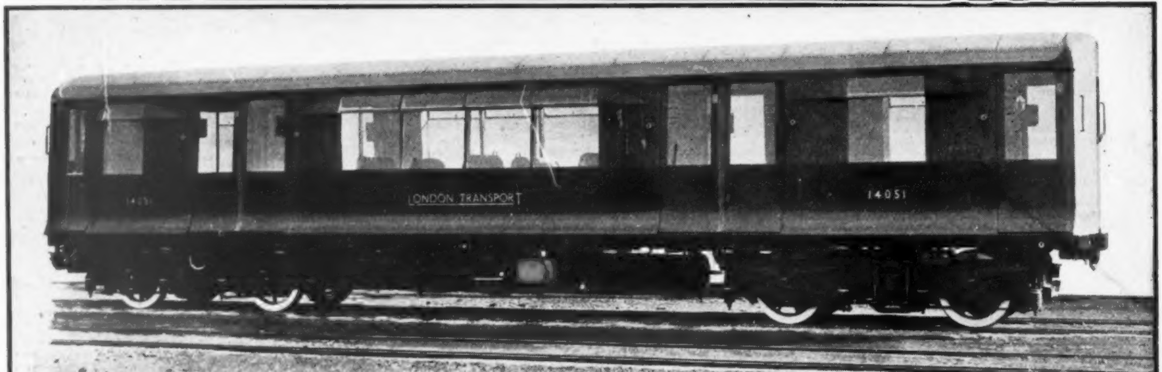

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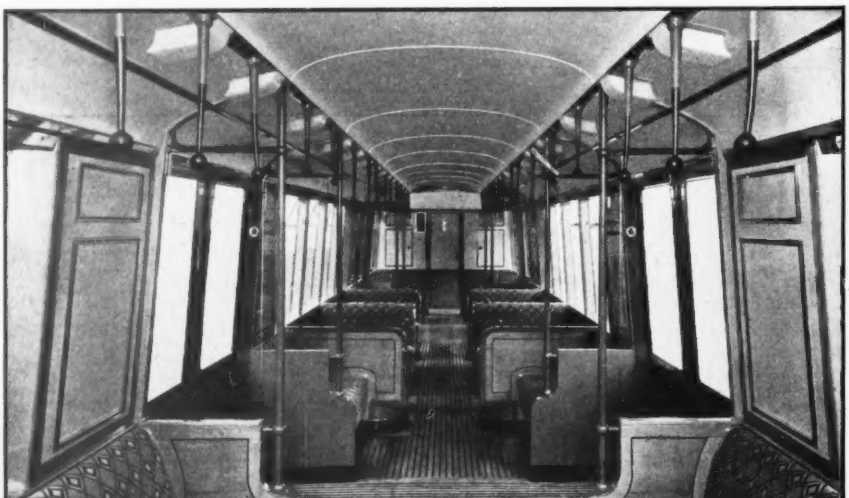

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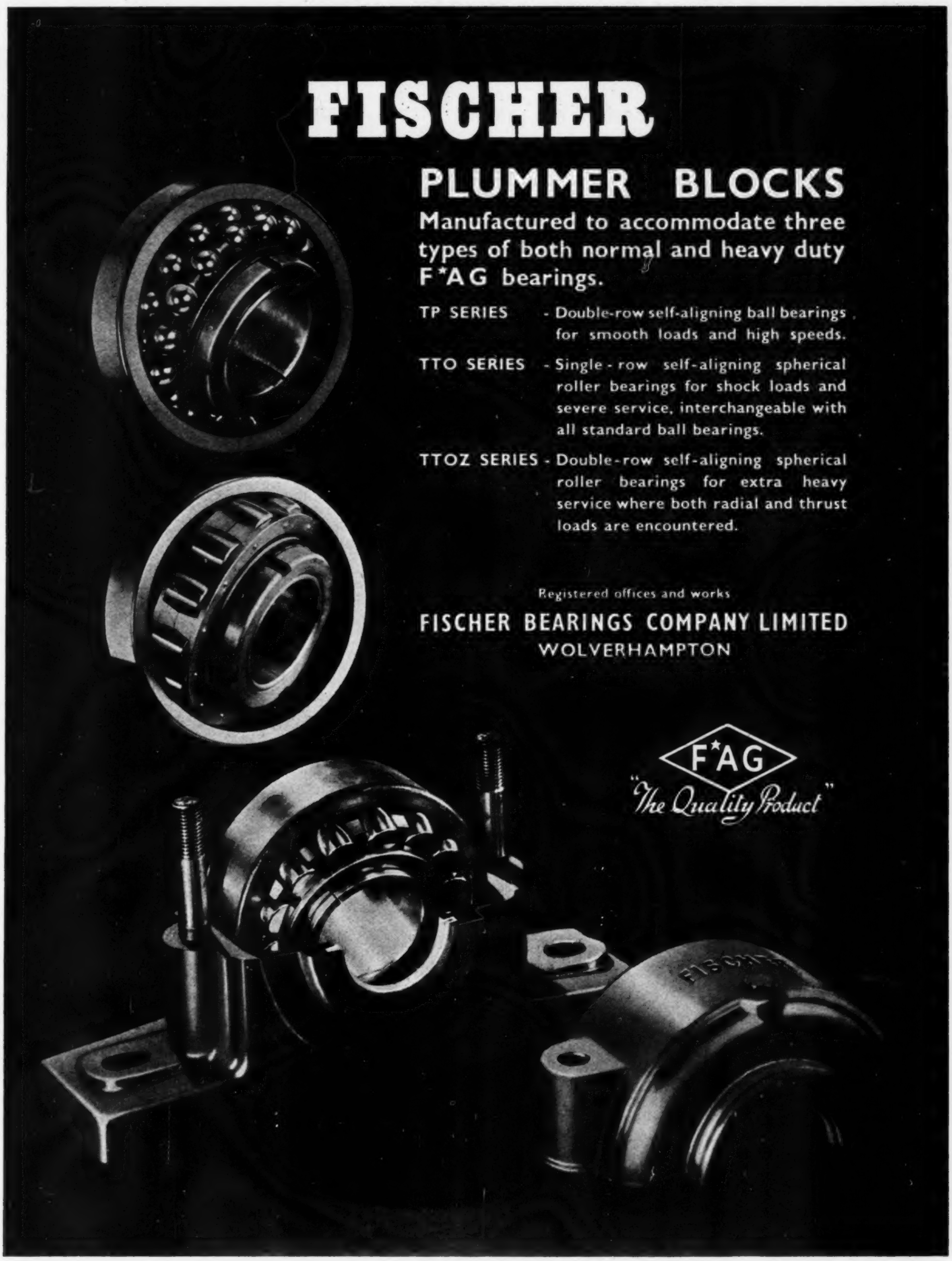
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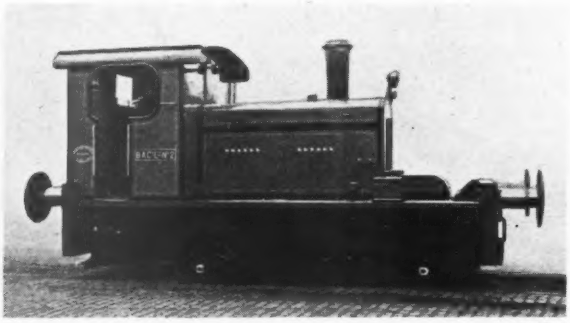

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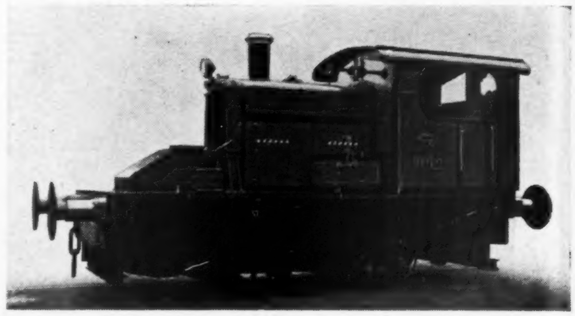

A

By courtesy of Messrs. John Fowler & Co. (Leeds) Ltd., the builders.

A. 80/85 B.H.P. Locomotive supplied to Whitehead Iron & Steel Co., Ltd.

B. 60/66 B.H.P. Locomotive supplied to British Aluminium Co., Ltd.

C. 60/66 B.H.P. Locomotive supplied to Messrs. Fredk. Braby & Co., Ltd.

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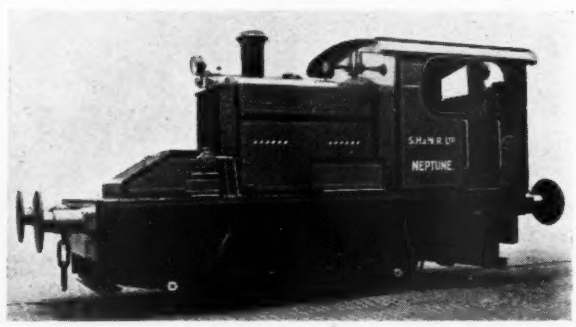
C

D



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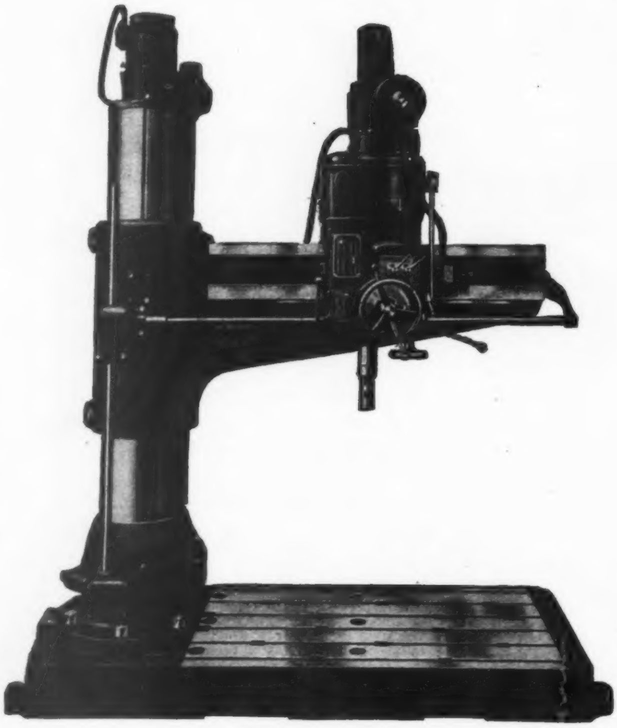

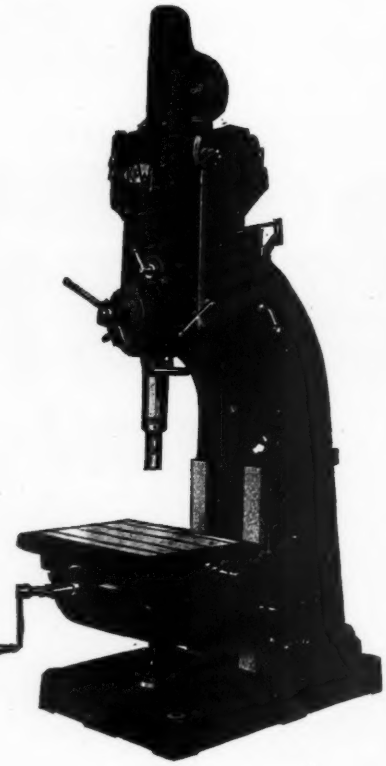

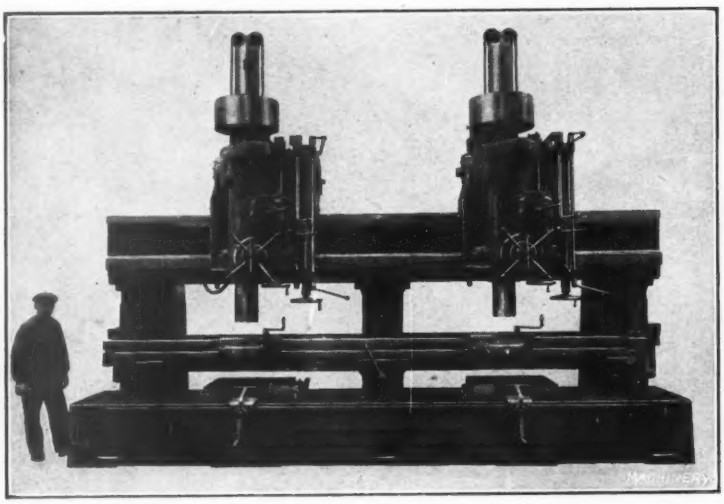

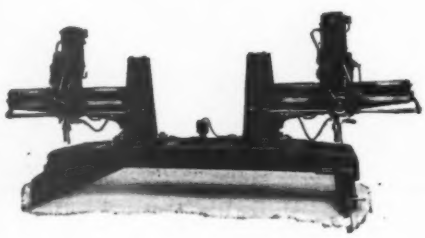

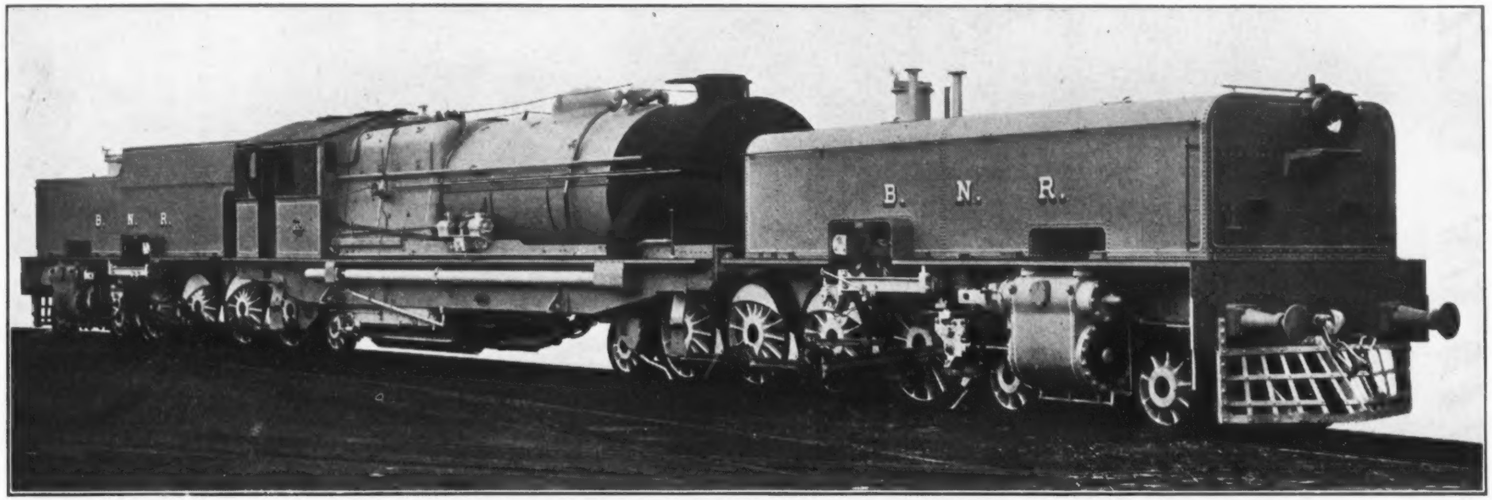
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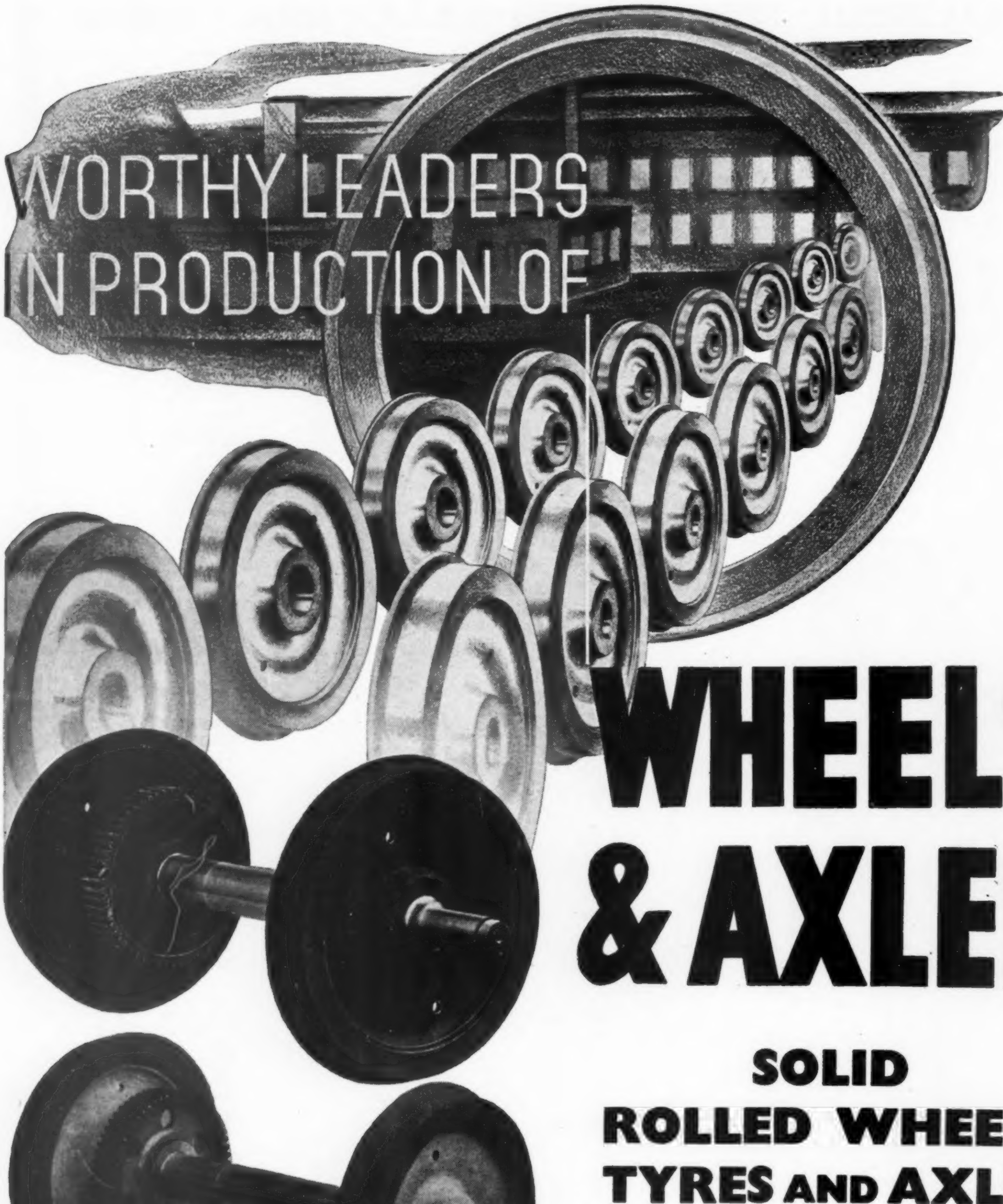
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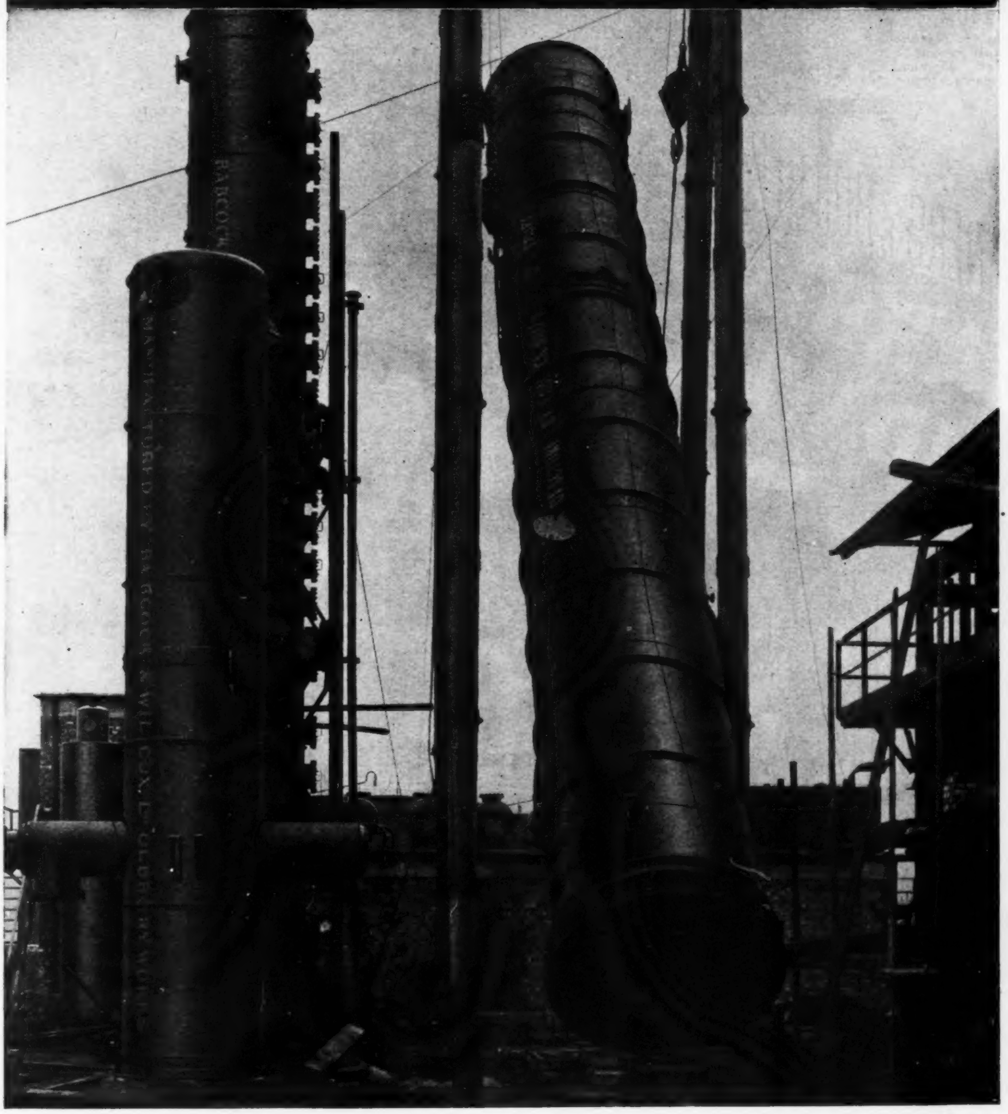

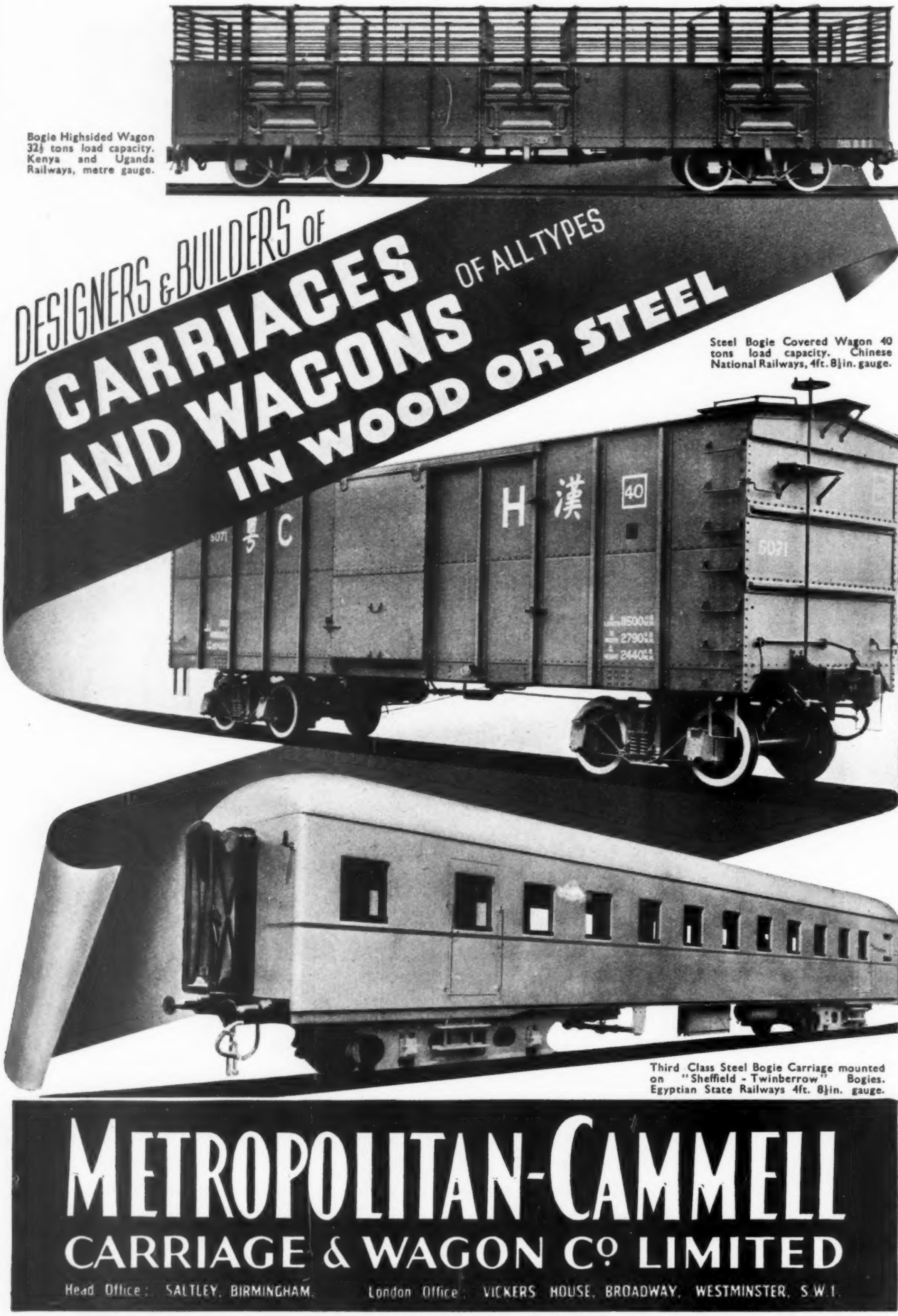

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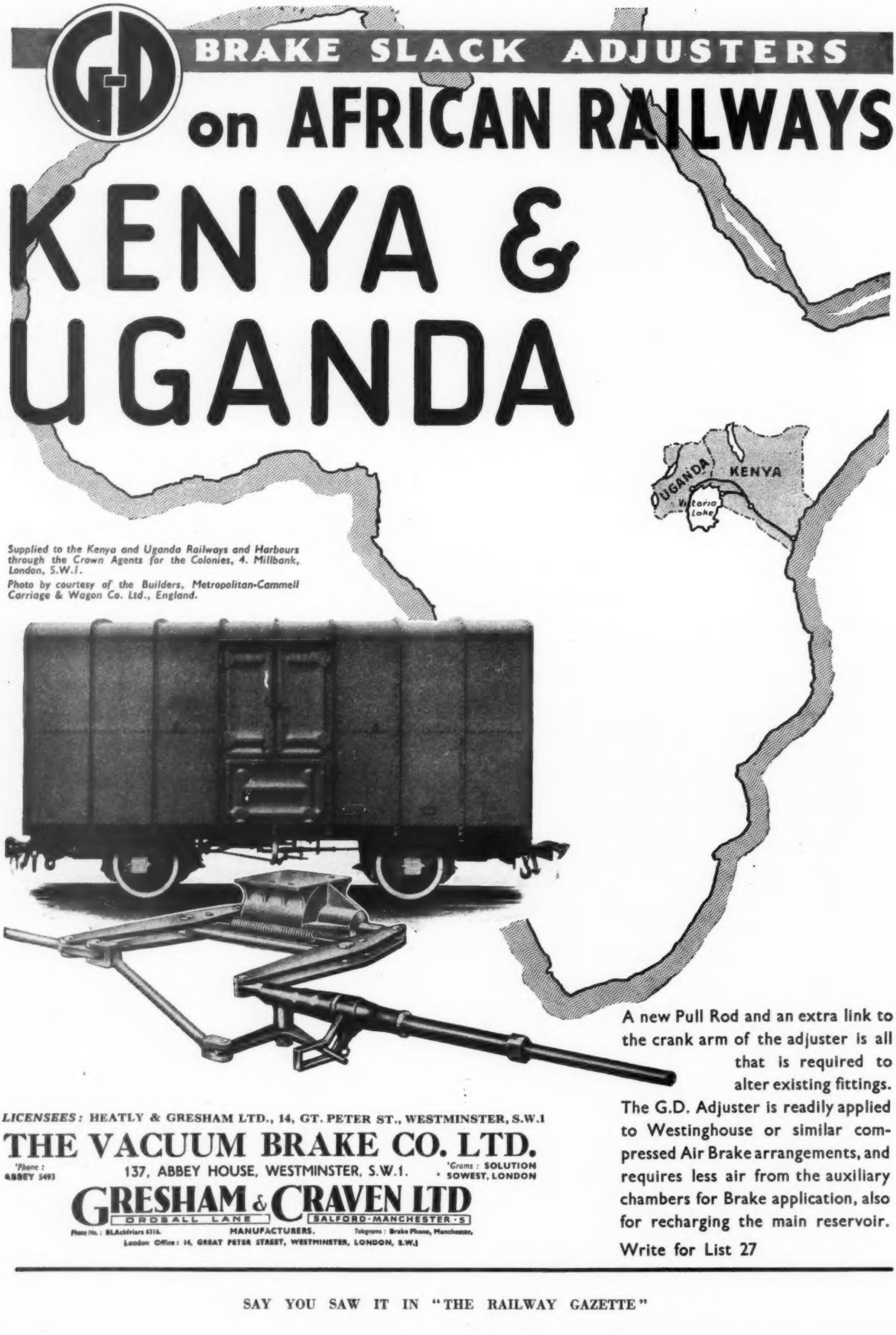
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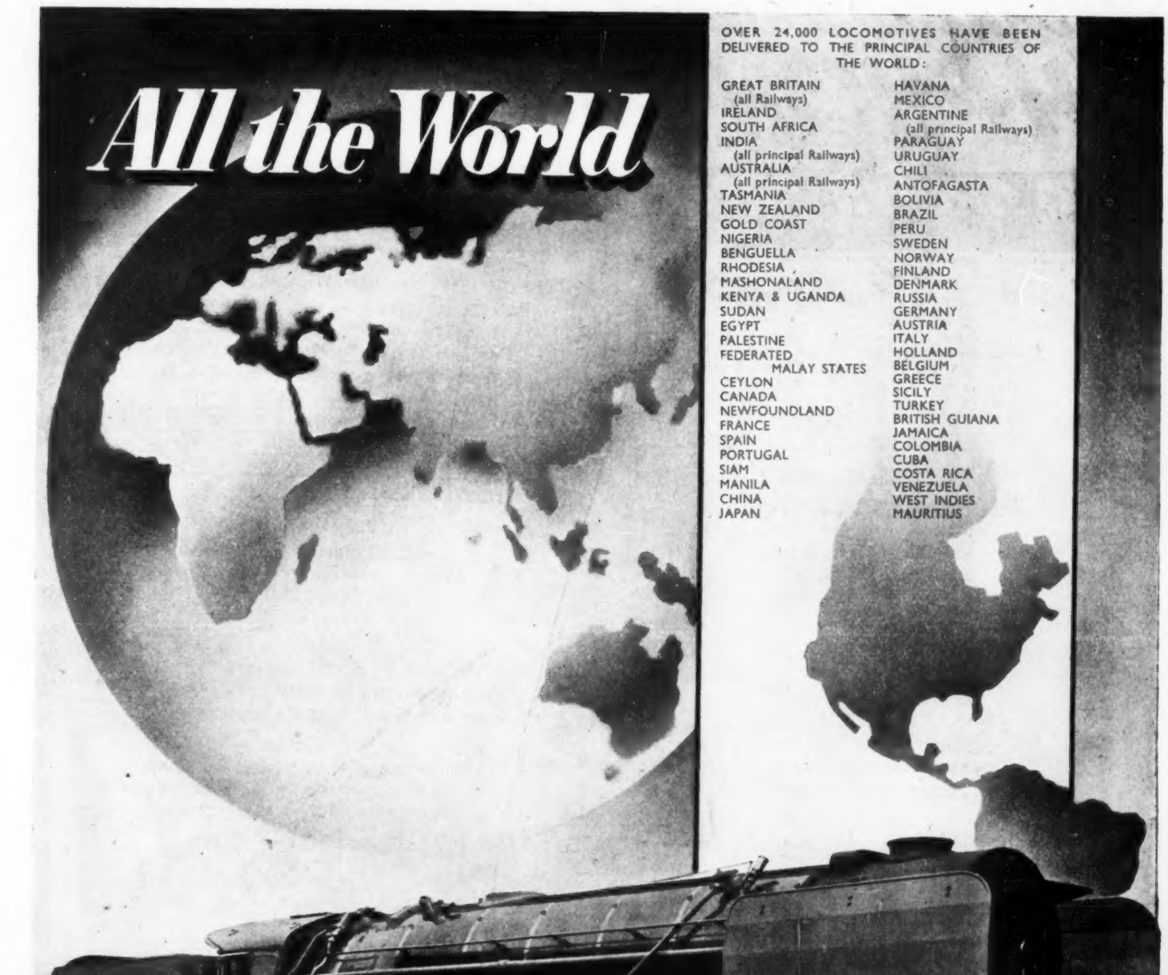

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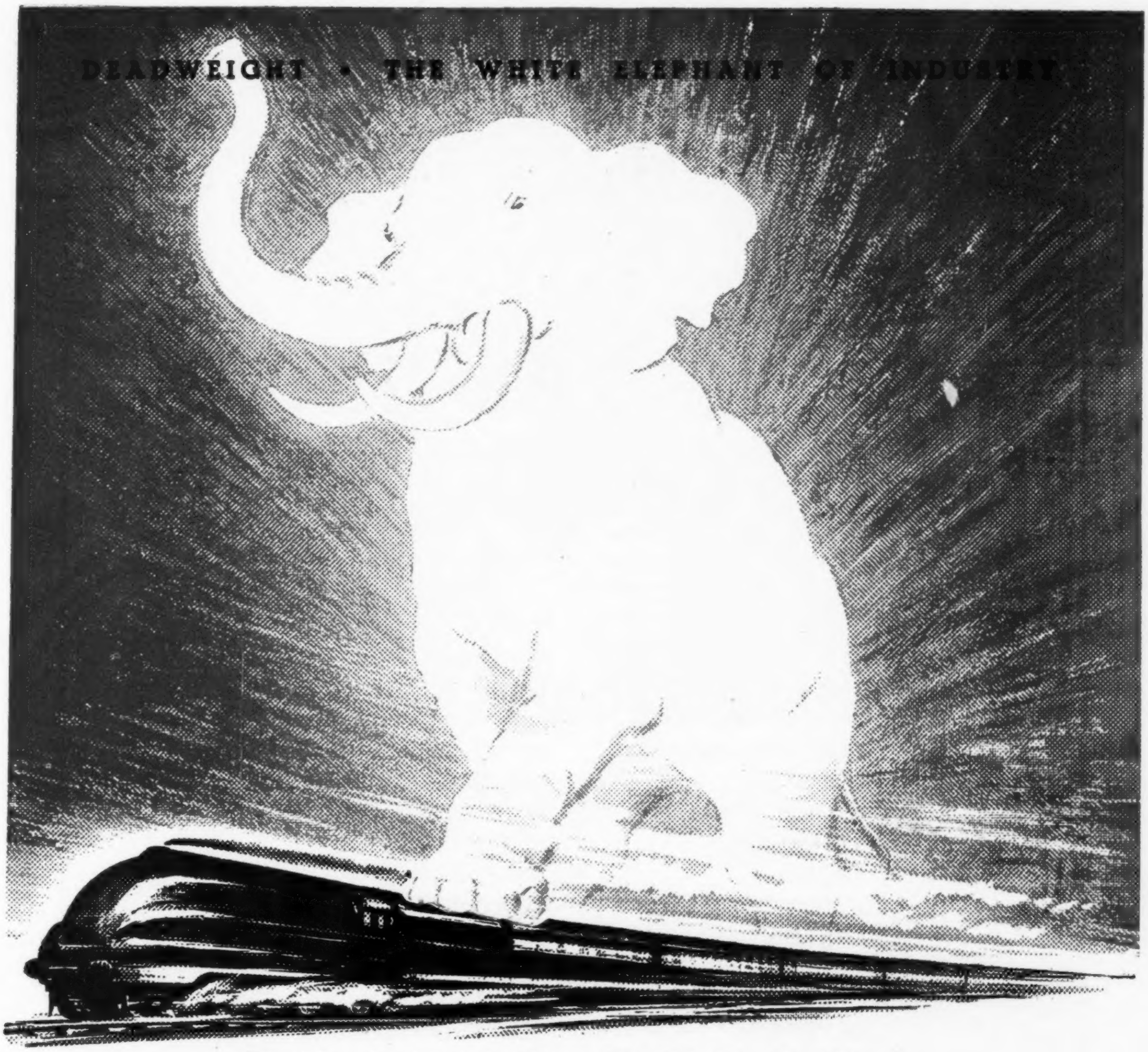

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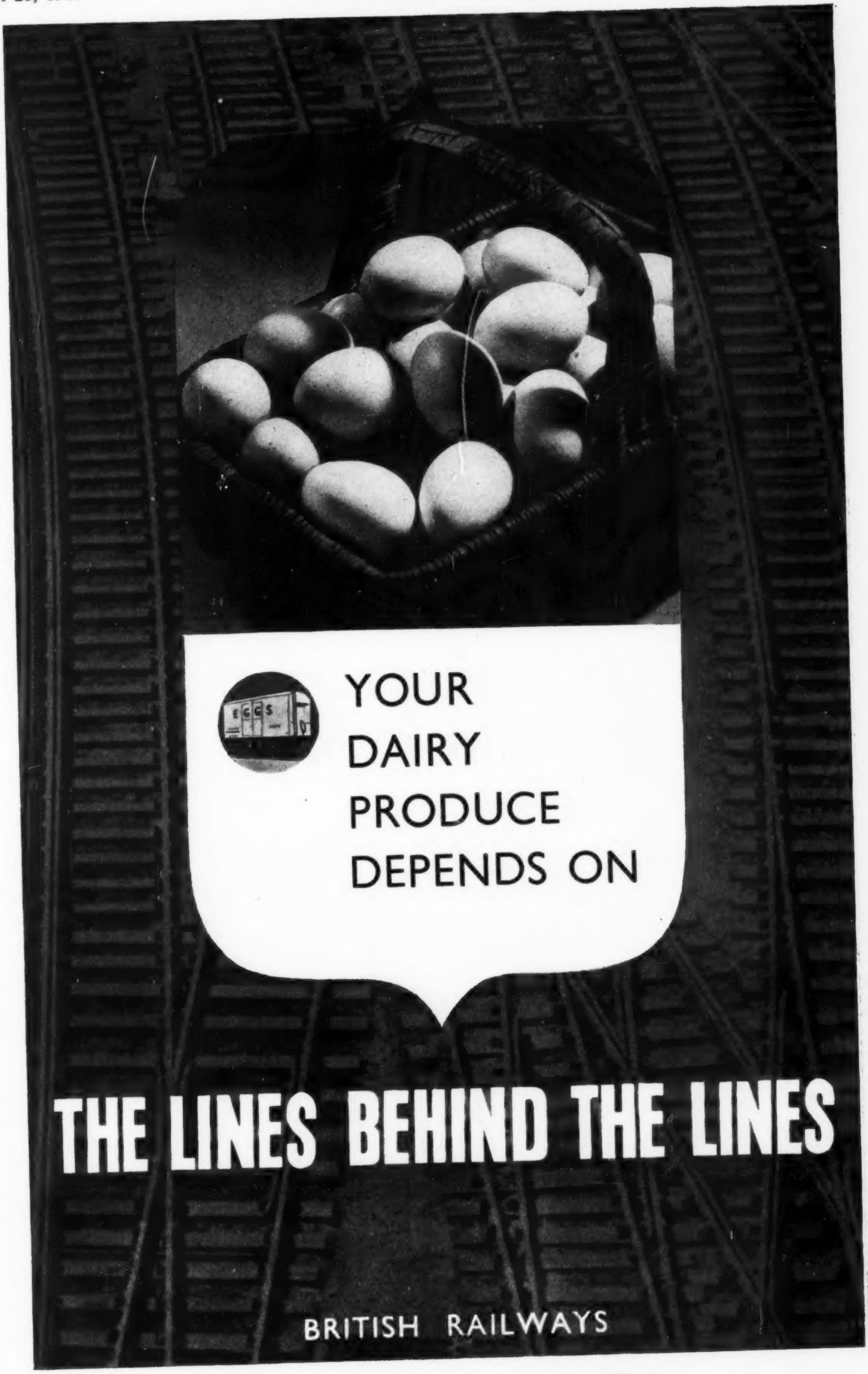
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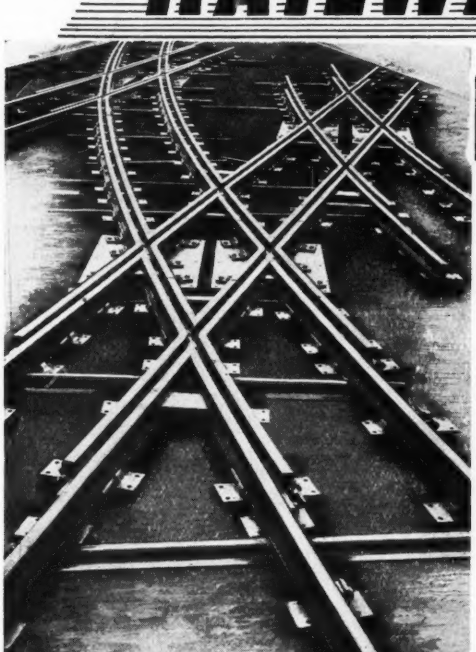

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